FINAL REPORT APPENDICES
General Investigation

SOMERSET & SEARSBURG DAMS
(Deerfield River Watershed Study)
Greenfield, Massachusetts

US ARMY CORPS
OF ENGINEERS
New England District

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APPENDIX 1 - Hydrologic and Hydraulic Appendix

Hydrologic and Hydraulic Analysis
Green River
Greenfield, Massachusetts

1. Introduction.

This hydrologic and hydraulic analysis was conducted to provide an assessment of dam configuration alternatives within the Green River watershed to determine the optimum channel configuration in order to enhance local and anadromous fisheries. Dams on the Green River in Greenfield, MA have restricted migratory and local fish species from accessing upstream historic spawning and nursery habitat areas resulting in the loss of fish populations. This general investigation study was conducted by the New England District of the Corps of Engineers in negotiated agreement with the Commonwealth of Massachusetts Executive Office of Environmental Affairs and was conducted under the Section 206 Environmental Restoration Authority.

The purpose of this study was to analyze structural alternatives at Wiley and Russell, Mill Street, Town Swimming Pool, and Pumping Station Dams to increase fish passage to areas upstream. This was accomplished using the Corps of Engineer's HEC-RAS standard step backwater model. Independent fish ladder and fish passage facility design was conducted for all four dams within the study area by the U.S. Fish and Wildlife Service (USFWS). Fish passage facility designs were not part of the hydraulic analysis; all technical analysis for these facilities was conducted by the USFWS. The Corps' hydraulic analysis examined five restoration alternatives for the four dams on the Green River: existing conditions (no structural alterations), a partial breach at Wiley and Russell Dam, a partial breach at Mill Street Dam, removal of Wiley and Russell Dam, and removal of Wiley and Russell and Mill Street Dams.

2. Description of Study Area.

a. General. The study area extends from the Greenfield – Colrain, MA corporate limits just upstream of Pumping Station Dam, downstream along the Green River to its confluence with the Deerfield River. The Green River originates in the Hogback Mountains in Marlboro, VT and flows in a generally southerly direction. Total length of the study reach is approximately 8.5 miles on the Green River, all of which is within the Greenfield, MA corporate limits. Drainage areas along the study reach increase from 52.2 square miles at the corporate limits just upstream of Pumping Station Dam to 89.7 square miles at the confluence of the Green River with the Deerfield. Significant tributaries to the Green River include Hinsdale, Allen, and Cherry Rum Brooks with drainage areas of 6.4, 3.2, and 11.1 square miles, respectively. The 4 dams on the Green River located in the study reach from upstream to downstream are Pumping Station Dam, Town Swimming Pool Dam, Mill Street Dam, and Wiley and Russell Dam. A map of the Green River, which is part of the Deerfield River Basin, is shown on Plate 1.

The Green River basin is characterized by rocky relatively steep slopes and narrow valleys in the upper reaches and a narrow flat plain in the lower reaches. Approximate elevations in the basin vary from 140 ft., NGVD at the most downstream dam to 2,400 ft., NGVD at the headwaters. The Green River floodplain in Greenfield mainly is narrow, flat, and deforested, and development is mostly commercial and residential. In the upper reaches, the floodplain is mostly wooded with sparse residential development (Plate1).

b. Dams. Following is a brief description of the four dams within the study reach in downstream order. This information was obtained from previous studies of the Green and Deerfield River Basins.

(1) Pumping Station Dam. This dam, the most upstream in the study reach, is 8.3 miles above the confluence of the Green and Deerfield Rivers. Owned and operated by the Town of Greenfield for water supply, it is a concrete structure about 14 feet high with a 95-foot wide spillway that has a crest elevation at 242.0 feet, NGVD. . Modification of this dam to provide fish passage would provide 12 miles of additional habitat along the Green River.

(2) Town Swimming Pool Dam. This dam, approximately 2 miles upstream of the confluence of the Green and Deerfield Rivers, is owned by the Town of Greenfield and operated for recreation. It is a concrete structure with a hydraulic height of 2 feet and a spillway width of approximately 75 feet at a crest elevation of 153.7 feet, NGVD. The dam is equipped with 10 stoplog bays that allow the pool to be raised during the summer to elevation 158.0 feet, NGVD. The dam could be altered by notching one of the stoplog bays and/or adding a fish ladder. Modification of this dam would provide 4.6 miles of additional habitat along the Green River.

(3) Mill Street Dam. This dam is about 1.5 miles upstream of the confluence of the Green and Deerfield Rivers. Originally owned and operated by Greenfield Electric Light and Power, it no longer is used for power production and is considered a run-of-the-river dam. The new Mill Street Bridge spans two abutments that form the eastern and western edges of the dam. There is one low level outlet (operability unknown), but the dam is generally in good condition. It has a height of approximately 12 feet, and a spillway width of 160 feet at crest elevation 145.5 feet, NGVD. At this site, the removal or partial breach of the dam, and/or a fish ladder installation could be considered to restore fish passage, which would provide an additional 2.2 miles of riverine habitat along the Green River.

(4) Wiley and Russell Dam. This dam, approximately 1.2 miles upstream of the confluence of the Green and Deerfield Rivers, is a timber crib and concrete run-of-the-river structure with a height of approximately 14.5 feet, and a spillway width of approximately 180 feet at elevation 136.5 +/- feet, NGVD. The dam was originally constructed for water supply for a tap and die complex adjacent to the site, but has fallen into considerable disrepair. The Town of Greenfield owns the dam and has been issued orders by the Massachusetts Department of Environmental Management to repair it. At this site, removal or partial breach of the dam, and/or a fish ladder installation could be considered to restore fish passage, which would provide an additional 0.3 miles of riverine habitat along the Green River.

c. Climatology. The climate of the Green River watershed is characterized by wide ranging temperatures and generally uniform precipitation. The average annual temperature is around 45° F with January temperatures averaging 23° F and July temperatures averaging 70° F. The area experiences three types of storms: continental storms from the west, coastal storms from the south (hurricanes, nor'easters), and local intense thunderstorms on warm, humid summer days. The average annual precipitation over the watershed is approximately 47 inches. The minimum and maximum monthly precipitation for the Green River watershed is shown in Table 1. These values were recorded and calculated at Tully Lake in Royalston, MA from 1971 to present.

Table 1
Maximum, Minimum Monthly Precipitation

	Monthly Precipitation [in.]	
Month	**Minimum**	**Maximum**
January	1.1	8.1
February	0.9	5.8
March	1.7	6.6
April	1.2	7.6
May	1.2	8.0
June	1.0	8.4
July	1.8	7.8
August	1.0	9.7
September	1.0	7.9
October	1.4	7.4
November	1.7	7.1
December	1.0	7.5

3. Streamflow.

a. General. The U.S. Geological Survey (USGS) has recorded flows on the Green River at Colrain, MA (gage #01170100) from October 1967 to present. The drainage area at the Colrain gage is 41.40 square miles. The monthly mean streamflows for the Colrain gage for the period of record, 1967 – 2004, is shown in Table 2.

Table 2
Monthly Mean Streamflows
Green River near Colrain, MA

Month	**Mean Streamflow** [cfs]
January	72.0
February	76.5
March	162
April	251
May	129
June	74.3
July	35.3
August	28.1
September	29.2
October	52.1
November	87.6
December	90.4
Annual	89.9

b. Average Daily Flow. The average daily flow over the entire period of record for the Colrain, MA gage is approximately 90 cfs and was used in the HEC-RAS model to determine water levels in the marsh/open water habitat during a typical month. The U.S. Fish and Wildlife provided flow criteria to determine if natural fish passage (partial breach and/or complete dam removal) would be viable. The flow, also referred to as “fish flow”, is equal to four times the average daily flow. Therefore, the fish flow for the Green River is equal to 360 cfs. Refer to section 4.c. for further discussion of natural fish passage criteria. Flows of higher magnitude were then analyzed to define the extent of changing water levels, and possible erosion, and scour problems in the study area due to the increased velocities from the partial breach and dam removal alternatives.

c. Flood Flow. Estimated peak flood flows were taken from the Greenfield, MA Flood Insurance Study dated January 1980, adjusted to a location just upstream of the confluence of the Green and Deerfield Rivers, and then used in the HEC-RAS model. They were compared to past Corps of Engineers studies and appear reasonable and were used to analyze the effects of the proposed alternatives under high flow conditions. Table 3 contains the flood flows used in this study.

Table 3
Flood Flows
Green River

Flow Event	Peak Discharges (cfs) At Mouth (D.A. = 89.7 sq.mi.)	Peak Discharges (cfs) U/S of Mouth (D.A. = 87.5 sq.mi.)	Peak Discharges (cfs) U/S of Pumping Station Dam (D.A. = 52.2 sq.mi.)
10YR	5,610	5,470	3,685
50YR	9,410	9,185	6,150
100YR	11,280	11,030	7,360
500YR	16,775	16,350	11,145

4. Hydraulic Analysis.

a. General. The Corp's HEC-RAS computer program was used to model the effects of dam removal/partial breach alternatives and to determine water elevations and velocities for the existing and proposed restoration conditions. Flows ranging from the four times the average annual daily flow up to the 500YR flood flow were modeled to provide a detailed profile of the Green River elevations for several different flow conditions. These results are used to determine if minimum and maximum depth of water requirements will be met for the different restoration alternatives (this criteria was provided by U.S. Fish and Wildlife (Refer to Section 4.c.)), and to provide elevations and velocities used in determining if stream bank protection is needed. The proposed alternatives were compared to the existing conditions to define the effects on the river elevations and velocities at the areas of proposed restoration.

b. Dam Removal Alternatives. Hydraulic analyses were conducted for four dam removal alternatives involving only the Wiley and Russell, and Mill Street Dams; no structural alternatives were proposed or evaluated for Town Swimming Pool and Pumping Station Dams. In evaluating the proposed alternatives, a "partial dam removal" meant creating a breech in the center of the structure that was sized to approximate the hydraulic performance of the most restrictive natural channel section in the vicinity of the dam. "Complete dam removal" meant the total removal of the structure without considering bridge abutments, road supports or other restrictions that might limit the practical extent to which the dam could be removed. Furthermore, in evaluating partial or complete removal, it was assumed that there were no bedrock outcrops that would restrict flows through the constructed openings in the dams. USFWS conducted independent fish ladder and fish passage facility designs for all four dams. These fish passage facility designs were not included in the Corps hydraulic analysis, on the assumption that fish ladders can be incorporated into the dam structure without increasing upstream flood levels. Detailed hydraulic analysis of fish ladders will be conducted in design studies to ensure that they do not impact flood levels. The four alternatives are described below (see the main report for a detailed discussion of alternatives and plan formulation rational).

(1) Alternative 1: Removal of Wiley and Russell Dam. This alternative involves complete removal of this timber crib and concrete dam, but no removal actions at the Mill Street, Town Swimming Pool, and Pumping Station Dams.

(2) Alternative 2: Removal of Wiley and Russell, and Mill Street Dams. This alternative involves the removal of Wiley and Russell, and Mill Street dams, with no removal actions at the Town Swimming Pool, and Pumping Station Dams. The dam sites under this alternative will be left in nearly a natural (pre-dam) state. This alternative would primarily restore a natural river ecosystem.

(3) Alternative 3: Partial Removal of Wiley and Russell Dam. This involves the removal of approximately a 60-foot wide by 3-foot high section in the center channel portion of this dam, but no removal actions at the Mill Street, Town Swimming Pool, or Pumping Station Dams.

(4) Alternative 4: Partial Removal of Wiley and Russell, and Mill Street Dams. This involves the removal of approximately a 60-foot wide by 3-foot high section of Wiley and Russell, and a 55-foot wide by 4.5-foot high section of Mill Street Dam. No removal action would be taken at Mill Street, Town Swimming Pool, or Pumping Station Dams.

c. Criteria for Natural Fish Passage. USFWS provided criteria for partial or complete dam removal to allow migrating fish upstream, including removal parameters, allowable flow conditions, and the maximum allowable differences between upstream and downstream water surface elevations at the dams for natural fish passage. The plans for partial removal of the Wiley and Russell, and Mill Street dams were to create a breach centered at the middle of the spillway and equal to one-third its width. Removal heights were computed to meet USFS requirements that the maximum allowable differences between upstream and downstream water surface elevations across the remaining structure did not exceed 3 feet for a flow of 360 cfs (refer to Section 3.b.). A 3-foot difference or less would allow migrating fish to access areas upstream naturally without need for a fish passage facility. Dam removal sizes used in these analyses are listed in Table 4.

Table 4
Partial Breach Parameters

	Wiley and Russell	Mill Street
Removal Size	60-feet wide by 3-feet high	55-feet wide by 4.5-feet high

The complete dam removal alternatives assumed there would be no practical restrictions on entirely removing the structure and returning this section of the river to nearly a natural (pre-dam) state. It also assumed that there were no natural ledge or bedrock outcrops that might result in a greater than 3-foot change in water surface elevation at the site after the dam was completely removed. Fish passage facility designs (fish ladders) were conducted independently by USFWS for all four dams in the study reach, and were not part of the Corps' hydraulic analyses.

d. HEC-RAS Analysis. The Corps of Engineers HEC-RAS computer model was used to compute water surface profiles from the confluence of the Green and Deerfield Rivers upstream through the Town of Greenfield to approximately 100 feet upstream of the Pumping Station Dam. It is a standard step method for calculating water surface elevations for steady gradually varied flows based on river geometry and structures crossing the channel. Model input consists of channel geometry, hydraulic roughness coefficients, bridge and dam elevation data and structural geometry, and flow data.

Dimensions of the dams, bridges, and river channel cross sections through the study reach were obtained from the HEC-2 files for the Greenfield, MA Flood Insurance Study. Supplemental survey was conducted in November 2001 to better define existing conditions of the structure, channel, and surrounding topography at each of the dams. This new survey data was incorporated into the model to better define the existing conditions, and provided accurate elevation data for possible sediment quantities just upstream of the dams. For the purpose of this hydraulic model, it was assumed that sediment erosion upstream of the dams would not be enough to affect the hydraulics of flow or resulting water surface elevations following partial or complete dam removal. Refer to the Geotechnical Appendix for a discussion of the characteristics and erosion potential of the sediments. Plate 2 is a study area map showing the locations of the four dams, and the starting and ending limits of the 8.5-mile reach of the Green River used for the HEC-RAS analysis.

5. Study Results.

The HEC-RAS model was developed from just upstream of the confluence with the Deerfield River and extended to just upstream of the Pumping Station dam. Starting water surface elevations and flows for the flood-flow analyses were taken from the profiles and information in the Greenfield Flood Insurance Study. Starting water surface elevations for the “fish flow” were calculated by the normal depth computation in the HEC-RAS model using the slope of the stream bottom. Profiles were computed from just upstream of the confluence to above Pumping Station dam. Computed elevations and velocities are presented in table 5 for the only section of the river that showed differences between existing conditions and the four alternatives, which was from river station 1.119, approximately 175 below the Wiley and Russell dam to river station 2.98, about 1.5 miles above the Mill Street dam. The rest of the study reach showed no change in water surface elevations or velocities between existing conditions and the partial and complete removal alternatives at Wiley and Russell, and Mill Street dams. The information summarized in Table 5 is for average annual flow, and a series of high flow events including FEMA’s 10, 50, 100, and 500-year flood flows. Plates 3 and 4 present backwater profiles from River Station 1.11 to River Station 3.16 for existing conditions and alternative 2, respectively. Alternative 2 was presented because it represents the most significant change in water surface elevations and channel velocities from the existing conditions.

Analyzed flows ranged from four times the average daily flow (“fish flow”), 360 cfs, to the 500-year flood event of 16,350 cfs. Results from this range of flows defined the local flow characteristics needed to identify whether the alternatives would meet the natural fish passage criteria, and define possible areas susceptible to scour and erosion due to velocity increases. The fish flow was used to model the maximum allowable flow that a migratory fish could overcome with a water surface upstream and downstream elevation difference of less than 3 feet at the altered dams. The HEC-RAS model results for this flow determined that for all four alternatives the water surface elevation difference was greater than 3 feet. This indicates that partial removal alternatives (Alt. 3 and 4) for natural fish passage might not be viable solutions at Wiley and

Russell, and Mill Street dams. Further investigation on depth, and particle size of the sediments behind the dams would need to be conducted to better define the actual elevation difference between the upstream and downstream inverts at Wiley and Russell, and Mill Street dams for the complete removal alternatives (Alt. 1 and 2).

The higher flows were analyzed to determine the velocities and elevations in the main channel for the four alternatives. The velocities provide information needed in the planning and design for any needed stream bank protection. Velocity increases upstream and downstream of Wiley and Russell, and Mill Street dams for 10 to 500-year flows ranged from 4-5 fps for the proposed Alternative Plans 1 and 2 (refer to Table 3). For Alternative plan 3, the velocities all increase upstream and downstream of Wiley and Russell dam. For Alternative plan 4, the velocity increases ranged from 1-2 ft/s upstream and downstream of Mill Street dam.

6. Erosion Prone Areas.

Sediments and riverbanks in the areas upstream and downstream of Wiley and Russell and Mill Street dams are mainly fine-grained soils prone to sloughing and erosion (Refer to Geotechnical Appendix). From reviewing the HEC-RAS results presented in Table 5, three potential problem areas were identified: upstream and downstream of Wiley and Russell Dam, upstream of Mill Street dam at Mill Street Bridge, and approximately 950 feet downstream of Mill Street Dam, Green River Cemetery (Refer to Geotechnical App.).

Areas upstream and downstream of the Green River Cemetery, approx. 950 feet downstream of Mill Street dam, do not experience significant fluctuations in the water surface elevations or increases in velocities for any of the alternatives. Refer to Table 5, for the water surface elevations, and channel velocities for the existing conditions and the alternatives. A velocity increase of less than 1 foot per second is experienced in the area of the cemetery, but that would not significantly increase the potential for erosion and sloughing of the banks.

Areas upstream of Mill Street dam experience some velocity increases with a significant increase at the upstream face of Mill Street bridge for alternatives 2 and 3. The velocity increases for Alternatives 2 and 3 are between 0.5 - 3 feet per second from river station 1.498, the downstream face of Mill Street dam, upstream to 1.933. The velocity increases at river station 1.514, upstream face of Mill Street bridge, and river station 1.499, the upstream face of Mill Street dam, were between 4-5 feet per second. Refer to Table 5, for the water surface elevations, and channel velocities for the existing conditions and the alternatives. The velocity increases in the 1-3 feet per second range most likely would not require stream bank protection. The velocity increase at river stations 1.499 and 1.514 is significant enough to cause erosion and sloughing of the existing sediments and riverbanks. Further investigation would be needed to determine the most viable solution to potential erosion problems.

Upstream of Wiley and Russell dam, velocity increases range from approximately 4-5 feet per second at the upstream face of the dam, river station 1.153, to 100 feet upstream of the dam, river station1.173. The velocity increases upstream of river station 1.173 to river station 1.190 range 1-2 feet per second, but become insignificant further upstream. Refer to Table 5, for the water surface elevations, and channel velocities for the existing conditions and the alternatives. The velocity increases upstream of river station 1.190 would not require stream bank protection. The velocity increases of 4-5 feet per second between river stations 1.153 and 1.173 most likely would require some stream bank protection. Further investigation would be needed to determine the most viable solution to possible erosion problems.

7. Future Hydraulic Analyses. If the study proceeds to the next stage, the HEC-RAS model will need to be rerun with additional information at the sites of the Wiley and Russell, and Mill Street Dams to determine if a greater than 3-foot change in water surface elevation will remain after complete dam removal. Required additional information includes channel cross-section, geologic, and sediment data to better define expected channel conditions after dam removal. In addition, any constraints on dam removal, such as bridge abutments or road supports, will need to be specified. Additional data on channel sediment and geologic conditions are needed at the potential erosion sites to determine the degree of stream bank protection needed if either of the dams were removed. Finally, additional investigations should be made to determine if the removal of the dams would be likely to affect ice formation and possible jams on the river.

Table 5:
HEC-RAS Model Results

			Existing Cond.		Alternative 1[1]		Alternative 2[2]		Alternative 3[3]		Alternative 4[4]	
Station Desc.	**River Station**	**Flow**	CWSEL	VCH	CWSEL	VCH	CWSEL	VCH	CWSEL	VCH	CWSEL	VCH
D/S Face Meridian St. Bridge	1.119	Fish Flow	127	6.2	127	6.2	127	6.2	127	6.2	127	6.2
	1.119	10-YR	132.2	13.7	132.2	13.7	132.2	13.7	132.2	13.7	132.2	13.7
	1.119	50-YR	134.4	16.3	134.4	16.3	134.4	16.3	134.4	16.3	134.4	16.3
	1.119	100-YR	135.3	17.3	135.3	17.3	135.3	17.3	135.3	17.3	135.3	17.3
	1.119	500-YR	138.4	18.8	138.4	18.8	138.4	18.8	138.4	18.8	138.4	18.8
U/S Face Meridian St. Bridge	1.125	Fish Flow	127.6	4.7	127.6	4.7	127.6	4.7	127.6	4.7	127.6	4.7
	1.125	10-YR	133	13.8	133	13.8	133	13.8	133	13.8	133	13.8
	1.125	50-YR	135.8	15.9	135.8	15.9	135.8	15.9	135.8	15.9	135.8	15.9
	1.125	100-YR	137	16.7	137	16.7	137	16.7	137	16.7	137	16.7
	1.125	500-YR	140.3	18.6	140.3	18.6	140.3	18.6	140.3	18.6	140.3	18.6
100' D/S of Wiley & Russell Dam	1.134	Fish Flow	128	1.8	128	1.8	128	1.8	128	1.8	128	1.8
	1.134	10-YR	135.2	7.6	135.2	7.6	135.2	7.6	135.2	7.6	135.2	7.6
	1.134	50-YR	138.2	9.7	138.2	9.7	138.2	9.7	138.2	9.7	138.2	9.7
	1.134	100-YR	139.5	10.7	139.5	10.7	139.5	10.7	139.5	10.7	139.5	10.7
	1.134	500-YR	142.9	12.6	142.9	12.6	142.9	12.6	142.9	12.6	142.9	12.6
D/S Face of Wiley & Russell Dam	1.152	Fish Flow	128	1.4	128	1.4	128	1.4	128	1.4	128	1.4
	1.152	10-YR	136	3.3	136	3.3	136	3.3	136	3.3	136	3.3
	1.152	50-YR	139.6	4	139.6	4	139.6	4	139.6	4	139.6	4
	1.152	100-YR	141.2	4.3	141.2	4.3	141.2	4.3	141.2	4.3	141.2	4.3
	1.152	500-YR	145.3	4.8	145.3	4.8	145.3	4.8	145.3	4.8	145.3	4.8
U/S Face of Wiley & Russell Dam	1.153	Fish Flow	137	0.6	134.2	4.1	134.2	4.1	136	0.8	136	0.8
	1.153	10-YR	140.8	4	136.7	9.7	136.7	9.7	140.2	4.4	140.2	4.4
	1.153	50-YR	142.6	5.3	139.1	8.8	139.1	8.8	141.9	5.8	141.9	5.8
	1.153	100-YR	143.4	5.9	140.8	8	140.8	8	142.6	6.3	142.6	6.3
	1.153	500-YR	145.4	7	145	7.2	145	7.2	145.3	7.1	145.3	7.1
100' U/S of Wiley & Russell Dam	1.173	Fish Flow	137	1	134.9	2.8	134.9	2.8	136	0.8	136	0.8
	1.173	10-YR	140.7	6.5	137..9	11.2	137..9	11.2	140.2	4.4	140.2	4.4
	1.173	50-YR	142.3	8.7	139.6	13.2	139.6	13.2	141.9	5.8	141.9	5.8
	1.173	100-YR	142.9	9.6	140.3	13.9	140.3	13.9	142.6	6.3	142.6	6.3
	1.173	500-YR	144.6	11.7	144.2	12.2	144.2	12.2	145.3	7.1	145.3	7.1
200' U/S of Wiley & Russell Dam	1.190	Fish Flow	137.1	0.9	135.1	1.8	135.1	1.8	136.1	1.2	136.1	1.2
	1.190	10-YR	140.8	6.9	137.9	8.4	137.9	8.4	140.2	7.5	140.2	7.5
	1.190	50-YR	142.4	9.4	141.1	11.1	141.1	11.1	141.7	10.2	141.7	10.2
	1.190	100-YR	143.1	10.5	141.7	12.3	141.7	12.3	142.4	11.4	142.4	11.4
	1.190	500-YR	144.8	12.9	144.3	13.5	144.3	13.5	144.6	13.1	144.6	13.1

[1] Removal of Wiley and Russell dam [2] Removal of Wiley and Russell and Mill Street dams [3] Partial removal of Wiley and Russell dam
[4] Partial removal of Wiley and Russell and Mill Street dams

Table 5:
HEC-RAS Model Results

			Existing Cond.		Alternative 1[1]		Alternative 2[2]		Alternative 3[3]		Alternative 4[4]	
Station Desc.	**River Station**	**Flow**	CWSEL	VCH	CWSEL	VCH	CWSEL	VCH	CWSEL	VCH	CWSEL	VCH
	1.309	Fish Flow	137.1	1.35	135.9	2.7	135.9	2.7	136.3	2	136.3	2
	1.309	10-YR	142	6.2	141.6	6.6	141.6	6.6	141.8	6.5	141.8	6.5
	1.309	50-YR	144.2	7.7	143.9	8.1	143.9	8.1	144	8	144	8
	1.309	100-YR	145.2	8.4	144.9	8.6	144.9	8.6	145	8.5	145	8.5
	1.309	500-YR	147.5	9.8	147.5	9.9	147.5	9.9	147.5	9.8	147.5	9.8
950' D/S of Mill St. Dam (Green River Cemetery)	1.326	Fish Flow	137.2	0.9	136	1.4	136	1.4	136.4	1.2	136.4	1.2
	1.326	10-YR	142.2	5.6	141.9	5.9	141.9	5.9	142	5.8	142	5.8
	1.326	50-YR	144.5	7.4	144.2	7.6	144.2	7.6	144.3	7.5	144.3	7.5
	1.326	100-YR	145.4	8.1	145.2	8.2	145.2	8.2	145.2	8.2	145.2	8.2
	1.326	500-YR	147.7	9.7	147.7	9.7	147.7	9.7	147.7	9.7	147.7	9.7
	1.388	Fish Flow	137.2	1.4	136.2	2.1	136.2	2.1	136.5	1.9	136.5	1.9
	1.388	10-YR	142.5	6.8	142.2	6.9	142.2	6.9	142.3	7	142.3	7
	1.388	50-YR	144.8	8.5	144.5	8.9	144.5	8.9	144.6	8.7	144.6	8.7
	1.388	100-YR	145.7	9.3	145.5	9.6	145.5	9.6	145.6	9.4	145.6	9.4
	1.388	500-YR	148.1	10.7	148.1	11.2	148.1	10.7	148.1	10.7	148.1	10.7
250' D/S of Mill St. Dam	1.469	Fish Flow	137.3	1.5	136.6	2.1	136.6	2.1	136.8	1.9	136.8	1.9
	1.469	10-YR	143.1	6.7	142.9	6.9	142.9	6.9	143	6.8	143	6.8
	1.469	50-YR	145.5	8.7	145.3	8.9	145.3	8.9	145.3	8.8	145.3	8.8
	1.469	100-YR	146.4	9.6	146.3	9.6	146.3	9.6	146.3	9.6	146.3	9.6
	1.469	500-YR	148.8	11.1	148.8	11.2	148.8	11.2	148.8	11.2	148.8	11.2
	1.479	Fish Flow	137.4	2.1	136.8	3.1	136.8	3.1	136.9	2.8	136.9	2.8
	1.479	10-YR	143.6	5.9	143.4	6.1	143.4	6.1	143.5	6	143.5	6
	1.479	50-YR	146.2	7.2	146.1	7.3	146.1	7.3	146.1	7.2	146.1	7.2
	1.479	100-YR	147.4	7.7	147.2	7.8	147.2	7.8	147.2	7.7	147.2	7.7
	1.479	500-YR	149.8	9.1	149.8	9.1	149.8	9.1	149.8	9.1	149.8	9.1
D/ S Face of Mill St. Dam	1.498	Fish Flow	137.5	0.7	137	0.8	137	0.8	137.1	0.8	137.1	0.8
	1.498	10-YR	144.1	3.6	143.9	3.6	143.9	3.6	144	3.6	144	3.6
	1.498	50-YR	146.9	4.7	146.8	4.7	146.8	4.7	146.8	4.7	146.8	4.7
	1.498	100-YR	148.1	5.1	148	5.2	148	5.2	148	5.1	148	5.1
	1.498	500-YR	150.8	6.3	150.8	6.3	150.8	6.3	150.8	6.3	150.8	6.3
U/S Face of Mill St. Dam	1.499	Fish Flow	146.3	0.5	146.3	0.5	140.5	5.6	146.3	0.5	142.6	1.3
	1.499	10-YR	150.2	3.9	150.2	3.9	144.4	11.2	150.2	3.9	148.3	5
	1.499	50-YR	152	5.4	152	5.4	146.3	12.1	152	5.4	150.1	6.5
	1.499	100-YR	152.7	6	152.7	6	147	12.6	152.7	6	150.9	7.2
	1.499	500-YR	154.8	7.4	154.8	7.4	150.1	11.7	154.8	7.4	152.8	8.8

[1] Removal of Wiley and Russell dam [2] Removal of Wiley and Russell and Mill Street dams [3] Partial removal of Wiley and Russell dam
[4] Partial removal of Wiley and Russell and Mill Street dams

Table 5:

HEC-RAS Model Results

			Existing Cond.		Alternative 1[1]		Alternative 2[2]		Alternative 3[3]		Alternative 4[4]	
Station Desc.	**River Station**	**Flow**	CWSEL	VCH	CWSEL	VCH	CWSEL	VCH	CWSEL	VCH	CWSEL	VCH
D/S Face of Mill Street Bridge	1.506	Fish Flow	146.3	0.4	146.3	0.4	141.1	1	141.1	1	142.7	0.7
	1.506	10-YR	150.3	4	150.3	4	146.5	6	146.5	6	148.6	4.7
	1.506	50-YR	152.1	5.7	152.1	5.7	148.5	7.9	148.5	7.9	150.5	6.5
	1.506	100-YR	152.9	6.4	152.9	6.4	149.3	8.8	149.3	8.8	151.3	7.3
	1.506	500-YR	155.1	8.2	155.1	8.2	151.4	10.7	151.4	10.7	153.3	9.2
U/S Face of Mill Street Bridge	1.514	Fish Flow	146.3	0.7	146.3	0.7	141.4	5	141.4	5	142.7	2.3
	1.514	10-YR	150.1	6.4	150.1	6.4	146.9	10.2	146.9	10.2	148.3	8.1
	1.514	50-YR	151.8	8.9	151.8	8.9	149.3	11.9	149.3	11.9	150	10.9
	1.514	100-YR	152.5	10	152.5	10	150.3	12.6	150.3	12.6	150.7	12.1
	1.514	500-YR	154.5	12.6	154.5	12.6	152.8	14.5	152.8	14.5	152.3	15.1
	1.523	Fish Flow	146.4	0.7	146.4	0.7	141.8	2.7	141.8	2.7	142.7	1.8
	1.523	10-YR	150.3	5.7	150.3	5.7	147.7	8	147.7	8	148.7	7
	1.523	50-YR	152.2	7.9	152.2	7.9	150.2	9.7	150.2	9.7	150.7	9.2
	1.523	100-YR	153	8.8	153	8.8	151.3	10.3	151.3	10.3	151.6	10.1
	1.523	500-YR	155.3	10.8	155.3	10.8	154.2	11.8	154.2	11.8	153.9	12.1
150' U/S of Mill St. Dam	1.528	Fish Flow	146.4	0.8	146.4	0.8	141.8	3.4	141.8	3.4	142.7	2.3
	1.528	10-YR	150.3	6.2	150.3	6.2	147.6	9.1	147.6	9.1	148.6	7.8
	1.528	50-YR	152.2	8.1	152.2	8.1	150.2	10.5	150.2	10.5	150.6	9.9
	1.528	100-YR	153.1	8.9	153.1	8.9	151.3	10.9	151.3	10.9	151.6	10.5
	1.528	500-YR	155.7	10.2	155.7	10.2	154.5	11.4	154.5	11.4	154.3	11.7
	1.55	Fish Flow	146.4	0.7	146.4	0.7	142.1	2.9	142.1	2.9	142.8	2.9
	1.55	10-YR	150.5	5.7	150.5	5.7	148.4	7.6	148.4	7.6	149.1	6.9
	1.55	50-YR	152.5	7.7	152.5	7.7	150.9	9.1	150.9	9.1	151.2	8.8
	1.55	100-YR	153.4	8.4	153.4	8.4	152	9.7	152	9.7	152.2	9.5
	1.55	500-YR	155.9	10.1	155.9	10.1	154.9	10.9	154.9	10.9	154.7	11.1
	1.60	Fish Flow	146.4	0.5	146.4	0.5	142.4	1.4	142.4	1.4	143	1.1
	1.60	10-YR	150.9	4.7	150.9	4.7	149.2	5.6	149.2	5.6	149.7	5.3
	1.60	50-YR	153.1	6.1	153.1	6.1	151.9	7	151.9	7	152.1	6.9
	1.60	100-YR	154.1	6.6	154.1	6.6	153.1	7.4	153.1	7.4	153.2	7.3
	1.60	500-YR	157.1	6.8	157.1	6.8	156.3	7.4	156.3	7.4	156.2	7.6
	1.761	Fish Flow	146.4	1.5	146.4	1.5	142.9	4.8	142.9	4.8	143.2	4.2
	1.761	10-YR	151.2	9.1	151.2	9.1	150.1	10.6	150.1	10.6	150.4	10.2
	1.761	50-YR	153.4	11.7	153.4	11.7	152.6	12.9	152.6	12.9	152.7	12.7
	1.761	100-YR	154.3	12.5	154.3	12.5	153.5	13.7	153.5	13.7	153.6	13.6
	1.761	500-YR	157.6	10.2	157.6	10.2	156.9	11.4	156.9	11.4	156.8	11.7

[1] Removal of Wiley and Russell dam [2] Removal of Wiley and Russell and Mill Street dams [3] Partial removal of Wiley and Russell dam

[4] Partial removal of Wiley and Russell and Mill Street dams

Table 5:
HEC-RAS Model Results

			Existing Cond.		Alternative 1[1]		Alternative 2[2]		Alternative 3[3]		Alternative 4[4]	
Station Desc.	**River Station**	**Flow**	CWSEL	VCH	CWSEL	VCH	CWSEL	VCH	CWSEL	VCH	CWSEL	VCH
	1.924	Fish Flow	146.5	0.8	146.5	0.8	143.7	1.4	143.7	1.4	143.8	1.4
	1.924	10-YR	153.2	4.9	153.2	4.9	152.8	5	152.8	5	152.9	5
	1.924	50-YR	156.2	6.1	156.2	6.1	156.1	6.1	156.1	6.1	156.1	6.1
	1.924	100-YR	157.4	6.5	157.4	6.5	157.3	6.6	157.3	6.6	157.3	6.6
	1.924	500-YR	158.7	8.7	158.7	8.7	158.6	8.7	158.6	8.7	158.6	8.7
	1.933	Fish Flow	146.5	0.8	146.5	0.8	143.7	0.8	143.7	0.8	143.8	1.4
Just D/S of	1.933	10-YR	153.2	4.9	153.2	4.9	152.8	5.1	152.8	5.1	152.9	5.1
B&M R.R.	1.933	50-YR	156.2	6.2	156.2	6.2	156.1	6.2	156.1	6.2	156.1	6.2
Bridge	1.933	100-YR	157.4	6.7	157.4	6.7	157.4	6.7	157.4	6.7	157.4	6.7
	1.933	500-YR	158.7	8.9	158.7	8.9	158.6	9	158.6	9	158.6	9
	1.94	Fish Flow	146.5	0.9	146.5	0.9	143.7	1.5	143.7	1.5	143.8	1.5
Just U/S of	1.94	10-YR	153.2	5	153.2	5	152.9	5.2	152.9	5.2	152.9	5.1
B&M R.R.	1.94	50-YR	156.2	6.2	156.2	6.2	156.1	6.2	156.1	6.2	156.1	6.2
Bridge	1.94	100-YR	157.5	6.6	157.5	6.6	157.4	6.6	157.4	6.6	157.4	6.6
	1.94	500-YR	158.8	8.7	158.8	8.7	158.8	8.7	158.8	8.7	158.8	8.7
	1.962	Fish Flow	146.5	0.9	146.5	0.9	143.7	1.5	143.7	1.5	143.8	1.4
	1.962	10-YR	153.3	5	153.3	5	152.9	5.2	152.9	5.2	153	5.1
	1.962	50-YR	156.3	6.5	156.3	6.5	156.2	6.5	156.2	6.5	156.2	6.5
	1.962	100-YR	157.5	7	157.5	7	157.4	7	157.4	7	157.4	7
	1.962	500-YR	158.8	9.4	158.8	9.4	158.8	9.4	158.8	9.4	158.8	9.4
	1.981	Fish Flow	146.5	1.7	146.5	1.7	144.8	5.6	144.8	5.6	144.8	5.6
Just D/S of	1.981	10-YR	153.3	5.5	153.3	5.5	153	5.7	153	5.7	153	5.7
Route 2A	1.981	50-YR	156.3	6.6	156.3	6.6	156.2	6.7	156.2	6.7	156.2	6.7
Bridge	1.981	100-YR	157.5	7.2	157.5	7.2	157.5	7.2	157.5	7.2	157.5	7.2
	1.981	500-YR	158.9	9.5	158.9	9.5	158.9	9.5	158.9	9.5	158.9	9.5
	1.993	Fish Flow	146.5	1.6	146.5	1.6	145.5	2.9	145.5	2.9	145.5	2.9
Just U/S of	1.993	10-YR	153.4	5.4	153.4	5.4	153.1	5.7	153.1	5.7	153.1	5.6
Route 2A	1.993	50-YR	156.4	6.6	156.4	6.6	156.3	6.7	156.3	6.7	156.3	6.7
Bridge	1.933	100-YR	157.6	7.1	157.6	7.1	157.6	7.1	157.6	7.1	157.6	7.1
	1.933	500-YR	159.1	9.4	159.1	9.4	159.1	9.4	159.1	9.4	159.1	9.4
	2.012	Fish Flow	146.6	1.6	146.6	1.6	145.8	2.4	145.8	2.4	145.8	2.4
	2.012	10-YR	153.6	5.1	153.6	5.1	153.3	5.3	153.3	5.3	153.3	5.3
	2.012	50-YR	156.6	6.1	156.6	6.1	156.5	6.2	156.5	6.2	156.6	6.2
	2.012	100-YR	157.9	6.6	157.9	6.6	157.9	6.6	157.9	6.6	157.9	6.6
	2.012	500-YR	159.7	8.4	159.7	8.4	159.6	8.4	159.6	8.4	159.6	8.4

[1] Removal of Wiley and Russell dam [2] Removal of Wiley and Russell and Mill Street dams [3] Partial removal of Wiley and Russell dam
[4] Partial removal of Wiley and Russell and Mill Street dams

Table 5:
HEC-RAS Model Results

			Existing Cond.		Alternative 1[1]		Alternative 2[2]		Alternative 3[3]		Alternative 4[4]	
Station Desc.	River Station	Flow	CWSEL	VCH	CWSEL	VCH	CWSEL	VCH	CWSEL	VCH	CWSEL	VCH
	2.148	Fish Flow	146.9	2.1	146.9	2.1	146.6	2.3	146.6	2.3	146.6	2.3
	2.148	10-YR	154	8.1	154	8.1	153.7	8.4	153.7	8.4	153.8	8.3
	2.148	50-YR	157.2	7.3	157.2	7.3	157.2	7.5	157.2	7.5	157.2	7.4
	2.148	100-YR	158.7	6.6	158.7	6.6	158.6	6.7	158.6	6.7	158.6	6.7
	2.148	500-YR	160.8	6.9	160.8	6.9	160.8	6.9	160.8	6.9	160.8	6.9
	2.258	Fish Flow	147.2	1.4	147.2	1.4	146.9	1.5	146.9	1.5	146.9	1.5
	2.258	10-YR	155.2	5.8	155.2	5.8	155	5.9	155	5.9	155.1	5.9
	2.258	50-YR	157.8	6.4	157.8	6.4	157.8	6.4	157.8	6.4	157.8	6.4
	2.258	100-YR	159	6.2	159	6.2	159	6.3	159	6.3	159	6.3
	2.258	500-YR	161.2	6.7	161.2	6.7	161.2	6.7	161.2	6.7	161.2	6.2
	2.455	Fish Flow	147.5	1.9	147.5	1.9	147.3	2	147.3	2	147.3	2
	2.455	10-YR	156.1	7	156.1	7	156.1	7.1	156.1	7.1	156.1	7.1
	2.455	50-YR	158.7	7.9	158.7	7.9	158.7	8	158.7	8	158.7	8
	2.455	100-YR	159.8	8.2	159.8	8.2	159.8	8.2	159.8	8.2	159.8	8.2
	2.455	500-YR	161.9	9.2	161.9	9.2	161.9	9.2	161.9	9.2	161.9	9.2
	2.464	Fish Flow	147.5	2.6	147.5	2.6	147.4	2.8	147.4	2.8	147.4	2.8
D/S Face of	2.464	10-YR	156	8.4	156	8.4	155.9	8.4	155.9	8.4	155.9	8.4
Colrain Street	2.464	50-YR	158.1	11.5	158.1	11.5	158.1	11.6	158.1	11.6	158.1	11.6
Bridge	2.464	100-YR	159.1	12.5	159.1	12.5	159.1	12.5	159.1	12.5	159.1	12.5
	2.464	500-YR	160.8	15.2	160.8	15.2	160.8	15.2	160.8	15.2	160.8	15.2
	2.47	Fish Flow	147.6	2.5	147.6	2.5	147.4	2.7	147.4	2.7	147.4	2.7
U/S Face of	2.47	10-YR	156.5	8	156.5	8	156.4	8	156.4	8	156.5	8
Colrain Street	2.47	50-YR	160	9.4	160	9.4	160	9.4	160	9.4	160	9.4
Bridge	2.47	100-YR	159.4	12.1	159.4	12.1	159.4	12.1	159.4	12.1	159.4	12.1
	2.47	500-YR	160.3	16.3	160.3	16.3	160.5	16	160.5	16	160.3	16.3
	2.50	Fish Flow	147.7	2.4	147.7	2.4	147.6	2.5	147.6	2.5	147.6	2.5
	2.50	10-YR	157.2	6.3	157.2	6.3	157.1	6.4	157.1	6.4	157.1	6.4
	2.50	50-YR	161	6.7	161	6.7	161	6.7	161	6.7	161	6.7
	2.50	100-YR	161.1	7.8	161.1	7.8	161.1	7.8	161.1	7.8	161.1	7.8
	2.50	500-YR	163.8	8.5	163.8	8.5	163.8	8.5	163.8	8.5	163.8	8.5
	2.64	Fish Flow	148.4	2.3	148.4	2.3	148.3	2.4	148.3	2.4	148.3	2.4
	2.64	10-YR	157.8	6.6	157.8	6.6	157.8	6.6	157.8	6.6	157.8	6.6
	2.64	50-YR	161.7	5.1	161.7	5.1	161.7	5.1	161.7	5.1	161.7	5.1
	2.64	100-YR	162.1	5.6	162.1	5.6	162.1	5.6	162.1	5.6	162.1	5.6
	2.64	500-YR	164.8	5.5	164.8	5.5	164.8	5.5	164.8	5.5	164.8	5.5

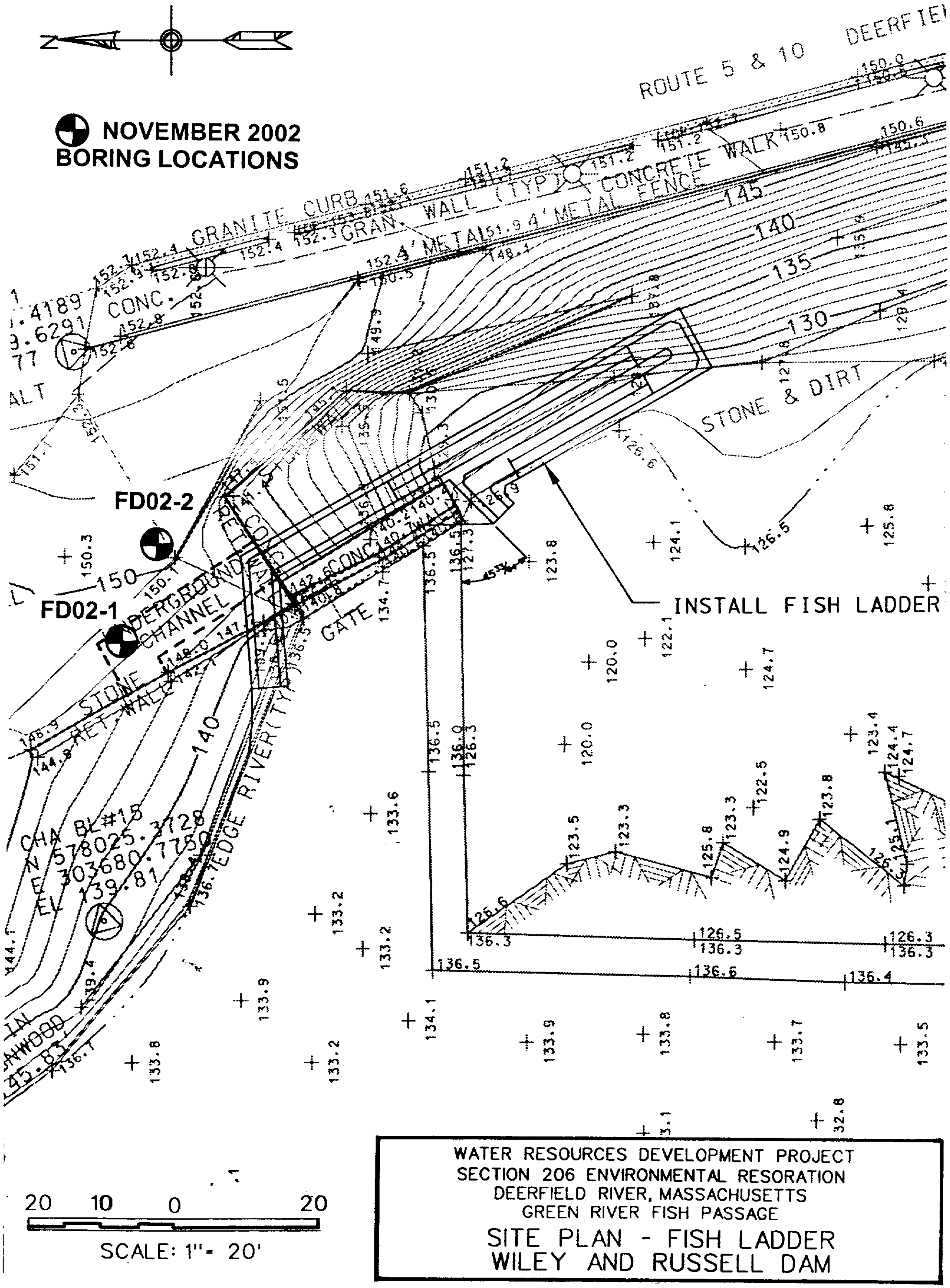
[1] Removal of Wiley and Russell dam [2] Removal of Wiley and Russell and Mill Street dams [3] Partial removal of Wiley and Russell dam
[4] Partial removal of Wiley and Russell and Mill Street dams

Table 5:
HEC-RAS Model Results

Station Desc.	River Station	Flow	Existing Cond. CWSEL	Existing Cond. VCH	Alternative 1[1] CWSEL	Alternative 1[1] VCH	Alternative 2[2] CWSEL	Alternative 2[2] VCH	Alternative 3[3] CWSEL	Alternative 3[3] VCH	Alternative 4[4] CWSEL	Alternative 4[4] VCH
	2.878	Fish Flow	149.3	2.2	149.3	2.2	149.3	2.2	149.3	2.2	149.3	2.2
	2.878	10-YR	158.9	6.1	158.9	6.1	158.8	6.2	158.8	6.2	158.8	6.2
	2.878	50-YR	162	6.7	162	6.7	162	6.7	162	6.7	162	6.7
	2.878	100-YR	162.6	7.5	162.6	7.5	162.6	7.5	162.6	7.5	162.5	7.5
	2.878	500-YR	165	8.5	165	8.5	165	8.5	165	8.5	165	8.5
	2.98	Fish Flow	149.3	2.2	149.3	2.2	149.3	2.2	149.3	2.2	149.3	2.2
	2.98	10-YR	158.9	6.1	158.9	6.1	158.8	6.2	158.8	6.2	158.8	6.2
	2.98	50-YR	162	6.7	162	6.7	162	6.7	162	6.7	162	6.7
	2.98	100-YR	162.6	7.5	162.6	7.5	162.6	7.5	162.6	7.5	162.5	7.5
	2.98	500-YR	165	8.5	165	8.5	165	8.5	165	8.5	165	8.5

[1] Removal of Wiley and Russell dam [2] Removal of Wiley and Russell and Mill Street dams [3] Partial removal of Wiley and Russell dam
[4] Partial removal of Wiley and Russell and Mill Street dams

APPENDIX 2 - Geotechnical Appendix


NOVEMBER 2002
BORING LOCATIONS
ROUTE 5 & 10
GRANITE CURB
GRAN. WALL (TYP)
CONCRETE WALK
4' METAL FENCE
CONC.
STONE & DIRT
FD02-2
FD02-1
UNDERGROUND CHANNEL
STONE RET. WALL
GATE
EDGE RIVER (TYP)
INSTALL FISH LADDER
CHA BL#15
N 578025.3728
E 303680.7750
EL 139.81
20 10 0 20
SCALE: 1"= 20'
WATER RESOURCES DEVELOPMENT PROJECT
SECTION 206 ENVIRONMENTAL RESORATION
DEERFIELD RIVER, MASSACHUSETTS
GREEN RIVER FISH PASSAGE
SITE PLAN - FISH LADDER
WILEY AND RUSSELL DAM

DRILLING LOG	DIVISION: U.S. Army Corps of Engineers	INSTALLATION: New England District, CENAE-EP-HG	SHEET 1 OF 2 SHEETS

1. PROJECT: Wiley & Russell Dam, Greenfield, MA	10. SIZE AND TYPE OF BIT: 2.5in.SPT w/300#-18in. drop
2. LOCATION (Coordinates or Station): DAM - Left Abutment Culvert N 578,023.0 E 303,720.0	11. DATUM FOR ELEVATION SHOWN (*TBM or MSL*): NGVD
3. DRILLING AGENCY: Subsurface Drilling & Remediation Co., Warwick, RI	12. MANUFACTURER'S DESIGNATION OF DRILL: Mobile B-61
4. HOLE NO. (*As shown on drawing title and file number*): FD02-1	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 8; UNDISTURBED 0
5. NAME OF DRILLER: Phil Thornsbury	14. TOTAL NUMBER CORE BOXES: 1
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED --- DEG. FROM VERT.	15. ELEVATION GROUND WATER: 132.8
	16. DATE HOLE: STARTED 11/04/2002; COMPLETED 11/05/2002
7. THICKNESS OF OVERBURDEN: 20.2	17. ELEVATION TOP OF HOLE: +149.3
8. DEPTH DRILLED INTO ROCK: 5.8	18. TOTAL CORE RECOVERY FOR BORING: 72 %
9. TOTAL DEPTH OF HOLE: 26.0	19. GEOLOGIST: MAV

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOV-ERY e	BOX OR SAMPLE NO. f	N Value (blows / foot) g	REMARKS (*Drilling time, water loss, depth weathering, etc., if significant*) h
+149.3	0.0	SP-SM	Br., SAND, SP-SM		NS 0.0 2.0		Drove 2' SPT (300# hammer @ 18" drop) w/o casing as starter hole. Hit brick fill at 1 ft.
+148.3	1.0	Brick	Red, Brick (Fill)				
+147.3	2.0	Brick	Red, Brick & Mortar	75	S1 2.0 4.0	16	Drove 2' SPT. Brick in spoon tip. Blows: 8-6-10-12
+146.9	2.4	Topsoil	Dk.Br., Silty(10-20)SAND w/ roots, SM				
+146.7	2.6	Brick	Red, Brick & Motar				
+145.3	4.0	SM	Br.&Red, Silty(10-20)SAND w/tr. gr. & roots (Fill), SM	79	S2A(0.7') S2B(0.9') 4.0 6.0	9	Spun 6" casing to 3' then drove to 4', and wash out w/ roller bit. Drove 2' SPT. Blows: 5-5-4-8
+144.6	4.7	ML	Gr., F.Sandy(20-30)SILT w/tr. gr. & roots (Dry/Fill) (1/2" layer gr. silt), ML				
+143.3	6.0	ML	Gr., SILT (Dry/Fill), ML	71	S3 6.0 7.4	15+	Drove 2' SPT, spoon refusal at 7.4' Blows: 7-8-10/0.4'
+141.9	7.4	Granite Slab	Granite Culvert Roof Slab		NS 7.4 9.1		Drove casing to 7.4'. Roller bit (4-7/8in.) through granite slab.
+140.2	9.1	Void	Culvert Opening (air space)		Void 9.1 16.5		Culvert Opening (Water at invert, depth 16.5 ft.)

DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 149.3 | **Hole No. FD02-1**

PROJECT: Wiley & Russell Dam, Greenfield, MA | INSTALLATION: New England District, CENAE-EP-HG | SHEET 2 OF 2 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOV-ERY e	BOX OR SAMPLE NO. f	N Value (blows / foot) g	REMARKS (Drilling time, water loss, depth weathering, etc., if significant) h
			Culvert Opening (air space) *(continued)*				
+132.8	16.5						
		OL	Stratified Sediments (wet) (0.2'Dk.Br. Rotten Timber; 0.2'Gr. F.Sandy SILT; 0.2'Bk. Charcoal; 0.2'RedGr. Silty SAND; 0.2' Cement Motar in tip), OL	28	S4A(0.8') S4B(0.2') 16.5 19.4	4	Drove 2' SPT, spoon broke thru motar at 17.7', weight of hammer to 19.4', cement motar in spoon tip. Blows: WH-2-2/0.2'-WH/1.7'
+131.6	17.7						
		NR	(No Recovery)				
+129.9	19.4						
		SM	Br.Gr., Silty(20-30)SAND, SM	100	S5A(0.4') S5B(0.4') 19.4 20.2		Drove 2' SPT, spoon refusal at 20.2' Blows: 45-100/0.2'
+129.5	19.8						
		Rock	Red, Weathered Bedrock		NS 20.2 21.0		Set & drove 4-in. casing to 20.8', Roller bit to 21.0'
+128.3	21.0						
		Rock	(Core Loss)	72	C1 21.0 26.0		NX coring, times 1-3-3-3-3 min/ft 1.4 ft. core loss at top of run (assumed due to breakup of core)
+126.9	22.4						
		Rock	Br.Red, SANDSTONE (coarse grained w/ conglomerate phases) RQD=21%, DIP=30				
+123.3	26.0						
							Bottom of hole at 26.0 ft. Backfilled hole w/grout.

DRILLING LOG	DIVISION U.S. Army Corps of Engineers	INSTALLATION New England District, CENAE-EP-HG	SHEET 1 OF 2 SHEETS

1. PROJECT Wiley & Russell Dam, Greenfield, MA	10. SIZE AND TYPE OF BIT 2.5in.SPT w/300#-18in. drop
2. LOCATION (Coordinates or Station) DAM - Left Abutment Area N 578,018.0 E 303,733.0	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* NGVD
3. DRILLING AGENCY Subsurface Drilling & Remediation Co., Warwick, RI	12. MANUFACTURER'S DESIGNATION OF DRILL Mobile B-61
4. HOLE NO. *(As shown on drawing title and file number)* FD02-2	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 8; UNDISTURBED 0
5. NAME OF DRILLER Phil Thornsbury	14. TOTAL NUMBER CORE BOXES 1
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED --- DEG. FROM VERT.	15. ELEVATION GROUND WATER 134.3
	16. DATE HOLE: STARTED 11/05/2002; COMPLETED 11/06/2002
7. THICKNESS OF OVERBURDEN 16.3	17. ELEVATION TOP OF HOLE +150.3
8. DEPTH DRILLED INTO ROCK 5.2	18. TOTAL CORE RECOVERY FOR BORING 96 %
9. TOTAL DEPTH OF HOLE 21.5	19. GEOLOGIST MAV

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOV-ERY e	BOX OR SAMPLE NO. f	N Value (blows / foot) g	REMARKS *(Drilling time, water loss, depth weathering, etc., if significant)* h
+150.3	0.0	SP-SM	Br., SAND, SP-SM		NS 0.0 2.0		Drove 2' SPT (300# hammer @ 18" drop) w/o casing as starter hole.
+148.3	2.0	SP-SM	Gr., SAND w/silt & roots (1/2-in. layer silt)(Dry/Fill), SP-SM	50	S1 2.0 4.0	7	Drove 2' SPT Blows: 4-4-3-4
+146.1	4.2	SP-SM	Dr.Br., SAND w/silt & roots, (trace organics), SP-SM	92	S2(bot.1') 4.0 6.0	15	Drove 2' SPT Blows: 2-7-8-8
+145.7	4.6	SM	Gr.Br., silty(20-30)SAND, SM				
+145.3	5.0	SP-SM	Redish, SAND w/silt & rock frags(20-30)(Dry/Fill), SP-SM				
+144.3	6.0	SP-SM	Gr., SAND w/silt, SP-SM	42	S3 6.0 8.0	15	Drove 2' SPT Blows: 9-8-7-9
+143.9	6.4	SP-SM	Redish, SAND w/silt (Dry/Fill), SP-SM				
+143.5	6.8	NR	(No Recovery)				
+142.3	8.0	Fill	Red, Rock Frags w/trace Sand, (Moist/Fill)	42	S4 8.0 10.0	20	Set & Drove 4" casing, roller bit to 8' (loss drill water at 8') Drove 2' SPT Blows: 9-11-9-9
+140.3	10.0	Fill	Red, Rock Frags w/Sand(25-35), (Moist/Fill)	67	S5 10.0 12.0	36	Drove 2' SPT Blows: 12-20-16-15
+138.3	12.0						

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 150.3					Hole No. FD02-2	
PROJECT Wiley & Russell Dam, Greenfield, MA				INSTALLATION New England District, CENAE-EP-HG			SHEET 2 OF 2 SHEETS
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOV-ERY e	BOX OR SAMPLE NO. f	N Value (blows / foot) g	REMARKS (Drilling time, water loss, depth weathering, etc., if significant) h
		SM	Redish, silty(10-20)SAND w/Gravel(10-20), angular (Moist/Till), SM	71	S6 12.0 14.0	24	Drove 2' SPT Blows: 11-12-12-11
				71	S7 14.0 16.0	27	Drove casing, roller bit. Drove 2' SPT Blows: 9-11-16-26
+134.3	16.0						
		SM	-same- (Wet/Till), SM	67	S8 16.0 16.5	100+	Drove 2' SPT, Refusal at 16.3 ft. Blows: 100/0.3 ft.
+133.8	16.5						
		Rock	Red, SANDSTONE (medium grained) RQD=56%	97	C1 16.5 21.5		Drove casing, roller bit to 16.5 ft. NX coring times 7-7-6-4-4 min/ft
+128.8	21.5						
							Bottom of hole at 21.5 ft. Backfilled hole w/grout.

APPENDIX 3 - Sediment Chemistry Analysis

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US ARMY CORPS
OF ENGINEERS
New England District

Contract No. DACW33-01-D-0004
Delivery Order No. 06
December 12, 2001

FINAL DATA REPORT

Deerfield River Feasibility Study Field Sampling and Laboratory Testing for Sediment Samples from the Green River, Greenfield, MA

FINAL DATA REPORT

for

DEERFIELD RIVER FEASIBILITY STUDY FIELD SAMPLING AND LABORATORY TESTING FOR SEDIMENT SAMPLES FROM THE GREEN RIVER, GREENFIELD, MA

Submitted to

Department of the Army
U.S. Army Corps of Engineers
North Atlantic Division
New England District

Contract No. DACW33-01-D-0004
Delivery Order No. 06

December 11, 2001

Prepared by

Battelle Duxbury Operations
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ATTACHMENTS

1.0 INTRODUCTION

The objective of this work was to ascertain the chemical content of sediment in the Green River in connection with the possible removal of four dams. This work was conducted for the Corps of Engineers, North Atlantic Division New England District (NED).

This report presents the results of the physical and chemical analyses performed on selected sediments in the Green and Deerfield Rivers. Custody records for all samples collected are provided in Attachment 1. All final data and associated quality control results for grain size, total organic carbon (TOC), metals, polychlorinated biphenyls (PCBs) and polynuclear aromatic hydrocarbon (PAH) analyses are provided as attachments to this report. The complete details of the survey operation are provided in the *Field Survey Report for Deerfield River Feasibility Study Field Sampling and Laboratory Testing for Sediment Samples from Green River, Greenfield, MA* dated September 28, 2001.

1.1. Sample Collection

On September 5th and 6th, 2001, 10 sediment samples from sampling locations on the Deerfield and Green Rivers in Greenfield, MA, were collected with push cores and a Van Veen grab sampler. At each sampling location, three representative samples were taken within a 20 foot radius of the target location. The three samples were characterized separately and then homogenized into one composite sample to be analyzed for physical and chemical parameters. Table 1 provides a summary of the samples actually collected and the corresponding dates. Any deviations to field sample collection are detailed in Table 2. Figure 1 shows the overall perspective of the sampling locations on the Deerfield and Green Rivers (note station 9 at the top of the map). Figure 2 shows the enlarged area of stations 1 through 8 for more detail. Because of the minimal amount of sediment available at station AAK-002, a sediment core sample (AAK-002A) was collected approximately 200 feet upstream in a depositional area on 9/6/01 and submitted for grain size, TOC and metals analysis (insufficient material was available for organic analyses). Another sample from this location was collected on 10/22/01 for PAH and PCB analysis and is identified as sample 2A-R.

1.2. Sample Handling and Custody

Sediment cores and grab samples were kept cold and transported to Battelle after completion of sampling. Grab samples were homogenized in the field and sufficient material was collected for grain size and sediment chemistry and archiving. Upon receipt of the sediment samples at the laboratory, chain of custody was transferred to the Battelle staff member responsible for core descriptions and processing. All cores were stored on ice until processing, which occurred on September 7, 2001. Once the cores were processed (split, characterized, and homogenized), representative portions of the homogenized cores were placed into appropriate containers for physical and chemical analyses. At this point, custody was transferred to Battelle's sample custodian and samples were then logged into Battelle's log-in system and assigned a unique Battelle ID. All samples were sent directly to the appropriate laboratories for analysis. No trace of chemical or organic type odors was detected in the sediment samples.

Table 1. Summary of Individual Sediment Cores Collected, Deerfield River Feasibility Study, Greenfield, MA.

Sample Core ID	Replicate	Site and Depth	Collection Date
AAK-001	1	1 4.5 ft	9/5/01
AAK-001	2	1 3.6 ft	9/5/01
AAK-001	3	1 2.9 ft	9/5/01
AAK-002	1	2 <6 in.	9/6/01
AAK-002	2	2 <6 in.	9/6/01
AAK-002	3	2 <6 in.	9/6/01
AAK-002A	1	2A 0.8 ft	9/6/01
AAK-002A	2	2A 0.6 ft	9/6/01
AAK-002A	3	2A 0.7 ft	9/6/01
AAK-002A Resample (*)	1	2A 0.5 ft	9/22/01
AAK-002A Resample	2	2A 0.5 ft	9/22/01
AAK-002A Resample	3	2A 0.5 ft	9/22/01
AAK-003	1	3 <6 in.	9/6/01
AAK-003	2	3 <6 in.	9/6/01
AAK-003	3	3 <6 in.	9/6/01
AAK-004	1	4 1.7 ft	9/5/01
AAK-004	2	4 1.5 ft	9/5/01
AAK-004	3	4 1.6 ft	9/5/01
AAK-005	1	5 <6 in.	9/5/01
AAK-005	2	5 <6 in.	9/5/01
AAK-005	3	5 <6 in.	9/5/01
AAK-006	1	6 <6 in.	9/5/01
AAK-006	2	6 <6 in.	9/5/01
AAK-006	3	6 <6 in.	9/5/01
AAK-007	1	7 1.8 ft	9/5/01
AAK-007	2	7 1.6 ft	9/5/01
AAK-007	3	7 1.8 ft	9/5/01
AAK-008	1	8 <6 in.	9/5/01
AAK-008	2	8 <6 in.	9/5/01
AAK-008	3	8 <6 in.	9/5/01
AAK-009	1	9 <6 in.	9/5/01
AAK-009	2	9 <6 in.	9/5/01
AAK-009	3	9 <6 in.	9/5/01

(*) Site 2A was resampled to provide additional material to complete all analyses.

Table 2. Deviations to Station Locations of Individual Sediment Cores Collected, Deerfield River Feasibility Study, Greenfield, MA

Station	Deviations
AAK-001	No deviation from planned location
AAK-002	No deviation from planned location
AAK-002A	Added station during field collection to obtain core sample from area (client request)
AAK-003	No deviation from planned location
AAK-004	Differential GPS not working correctly; sample taken approximately 20 feet upstream of dam
AAK-005	No deviation from planned location
AAK-006	Sediment collected directly downstream of dam in only area where sediment collection was available
AAK-007	Sediment collected under bridge; immediately upstream of dam. Bridge prevented dGPS readings.
AAK-008	Insufficient sediment at planned location to obtain sediment sample; station moved slightly to obtain grab sample
AAK-009	Station moved slightly to obtain sufficient sediment sample

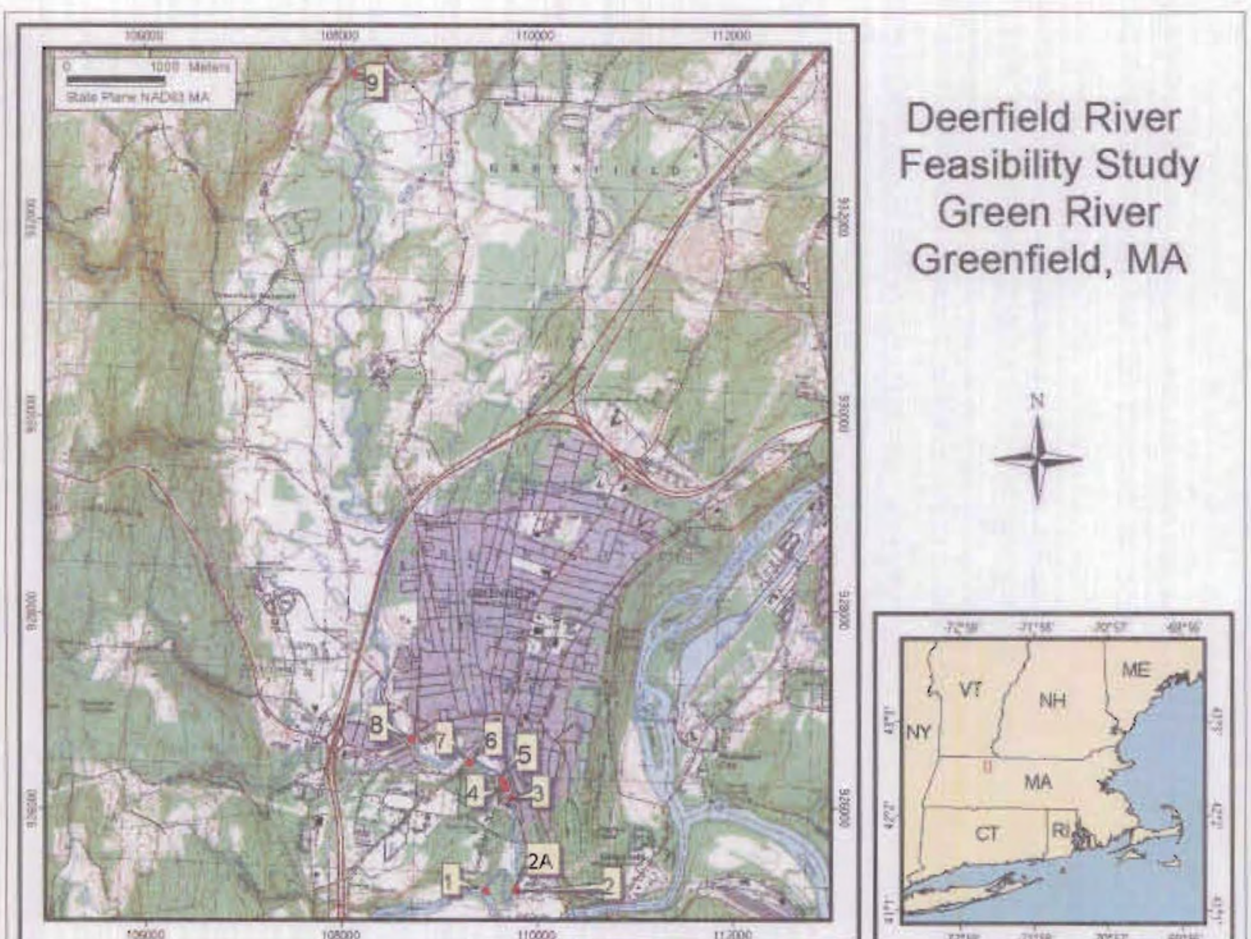

Figure 1. Site Map, Deerfield River Feasibility Study, Greenfield, MA

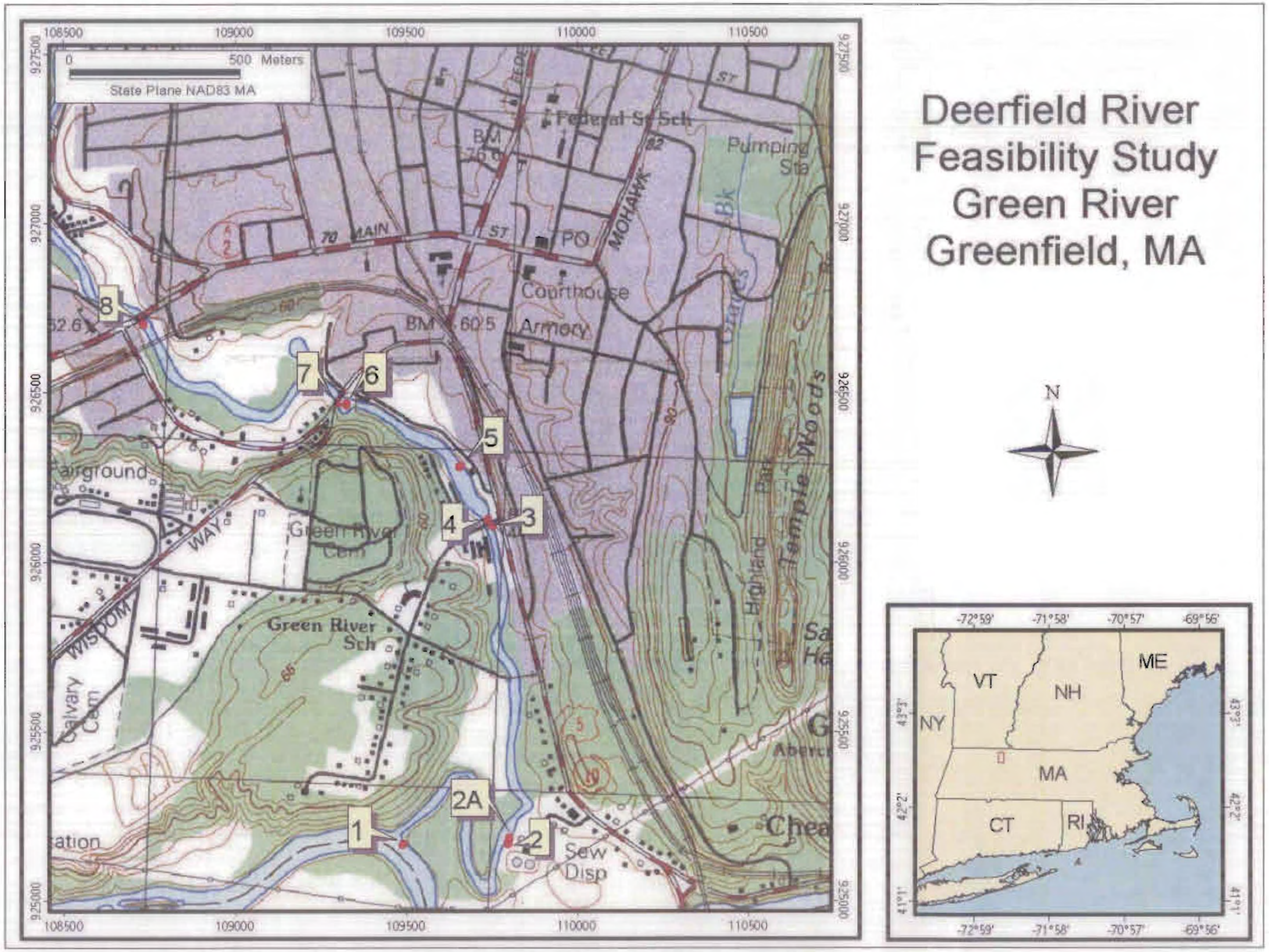

Figure 2. Enlarged View of Stations 1 through 8.

Sample ID	Station	Date	Latitude °N (NAD 27)	Longitude °W (NAD 27)
AAK-001 Rep 1	1	9-5-01	42° 34.3066'	72°36.1445'
" Rep 2	1	9-5-01	42°34.3071'	72°36.1432'
" Rep 3	1	9-5-01	42°34.3088	72°36.1438'
AAK-002 Rep 1	2	9-6-01	42°34.3117'	72°35.9207'
" Rep 2	2	9-6-01	42°34.3094'	72°35.9204'
" Rep 3	2	9-6-01	42°34.3110'	72°35.9180
AAK-002A Rep 1	2A	9-6-01	42°34.3203'	72°35.9160'
" Rep 2	2A	9-6-01	42°34.3199'	72°35.9162'
" Rep 3	2A	9-6-01	42°34.3206'	72°35.9162'
AAK-002A-R Rep 1	2A-R	10-22-01	42°34.3200'	72°35.9163'
" Rep 2	2A-R	10-22-01	42°34.3197'	72°35.9160'
" Rep 3	2A-R	10-22-01	42°34.3204'	72°35.9162'
AAK-003 Rep 1	3	9-6-01	42°34.8164'	72°35.9608'
" Rep 2	3	9-6-01	42°34.8160'	72°35.9613'
" Rep 3	3	9-6-01	42°34.8162'	72°35.9610'
AAK-004 Rep 1	4	9-5-01	*	*
" Rep 2	4	9-5-01	*	*
" Rep 3	4	9-5-01	*	*
AAK-005 Rep 1	5	9-5-01	42°34.9109'	72°36.0430'
" Rep 2	5	9-5-01	42°34.9100'	72°36.0337'
" Rep 3	5	9-5-01	42°34.9114'	72°36.0317'
AAK-006 Rep 1	6	9-5-01	42°35.0056'	72°36.2763'
" Rep 2	6	9-5-01	42°35.0073'	72°36.2770'
" Rep 3	6	9-5-01	42°35.0086'	72°36.2753'
AAK-007 Rep 1	7	9-5-01	*	*
" Rep 2	7	9-5-01	*	*
" Rep 3	7	9-5-01	*	*
AAK-008 Rep 1	8	9-5-01	42°35.1325'	72°36.7219'
" Rep 2	8	9-5-01	42°35.1310'	72°36.7132'
" Rep 3	8	9-5-01	42°35.1305'	72°36.7118'
AAK-009 Rep 1	9	9-5-01	42°38.7747'	72°37.1897'
" Rep 2	9	9-5-01	42°38.7756'	72°37.1883'
" Rep 3	9	9-5-01	42°38.7742'	72°37.1880'

*** No DGPS coverage, all samples taken within 15 feet of intended location.**

2.0 METHOD

Grain size and chemical analyses were performed on all individual samples collected from the field. Brief descriptions of the methods used are included below.

2.1 Grain Size Analyses

Grain size analyses were performed on the 10 individual samples. Water content and grain size distribution were determined by ASTM D-422. Grain size analyses were performed at Applied Marine Sciences (AMS) of League City, Texas.

2.2 Total Organic Carbon Analyses

Total Organic Carbon (TOC) was analyzed on the composite samples according to EPA Method 9060. TOC analyses were performed at Applied Marine Sciences (AMS) of League City, Texas. All samples were analyzed in duplicate and results are reported in % dry wt.

2.3 Metals Analyses

Fifteen metals were analyzed: silver (Ag), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr) copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), antimony (Sb), selenium (Se), thallium (Tl), vanadium (V), and zinc (Zn). Sediment samples were digested using aqua regia according to Battelle SOP MSL-I-006, *Mixed Acid Sediment Digestion*. An approximately 500-mg (dry weight) aliquot of each sample was combined with nitric and hydrochloric acids (aqua regia) in a Teflon bomb and heated in an oven at 130°C (±10°C) overnight. After heating and cooling, deionized water was added to the sediment digestate to achieve analysis volume, and the digestates were submitted for analysis. Sample digestates were analyzed by inductively coupled plasma-atomic emission spectrometry (ICP-AES) following Battelle SOP MSL-I-027, *Determination of Metals in Aqueous and Digestate Samples by ICP/AES*. Results of analysis for Ag, Ba, Cr, Cu, Ni, V, and Zn. Sample digestates were analyzed using inductively coupled plasma-mass spectrometry (ICP-MS) according to Battelle SOP MSL-I-022, *Determination of Elements in Aqueous and Digestate Samples by ICP/MS*. Results of analysis for As, Be, Cd, Pb, Sb, and Tl were reported. Selenium was analyzed by flow- injection atomic spectroscopy (FIAS) following a modification of SW846 Methods 7062 and 7742 instead of ICP/MS or ICP/AES as it is more sensitive for this metal and allowed us to achieve the detection limit required. Hg was analyzed using cold-vapor atomic absorption spectroscopy (CVAA) according to Battelle SOP MSL-I-016, *Total Mercury in Tissues and Sediments by Cold Vapor Atomic Absorption*. All results were reported in units of $\mu g/g$ on a dry-weight basis.

2.4 PCB Analyses

PCBs were extracted using methylene chloride. The extract was reduced in volume and cleaned using alumina column chromatography and HPLC. A portion of the extract was exchanged into hexane and analyzed for 22 individual PCB congeners using gas chromatography/electron capture detection (GC/ECD) following general National Oceanic and Atmospheric Administration (NOAA) National Status and Trends (NS&T) methods. Dual column confirmation was performed for all analytes.

2.5 PAH Analyses

PAHs were extracted along with PCBs as described above. Extracts were reduced, cleaned using alumina column chromatography and HPLC, and a portion of the extract analyzed in the selected ion monitoring (SIM) mode using gas chromatography/mass spectrometry (GC/MS) following general NOAA NS&T methods.

3.0 RESULTS

Results for all field samples and quality control samples are provided as attachments to this report.

3.1 Grain Size Results

Grain size analysis results, including water content and plots, were furnished by Applied Marine Sciences, Inc. from League City, Texas and are provided in Attachment 2 along with quality control results.

Grain Size – Individual Cores The core sediments were generally characterized as well-graded greenish-brown sand with trace small amounts of gravel. Table 3 summarizes the grain size distributions of the individual cores.

Table 3. Summary of Grain Size Results.

Sample Number	Gravel #4 (%)	Coarse Sand #10 (%)	Medium Sand #40 (%)	Fine Sand #200 (%)	Silt/Clay <0.074mm (%)	Water Content (%)
AAK-001	2.40	7.07	39.89	50.17	0.47	24
AAK-002	36.34	22.33	25.09	15.70	0.54	18
AAK-002A	24.85	16.00	43.81	15.14	0.21	43
AAK-003	15.59	9.25	65.06	9.48	0.62	18
AAK-004	16.65	7.13	55.63	20.56	0.03	20
AAK-005	2.29	11.52	78.08	6.88	1.23	25
AAK-006	39.05	26.03	33.82	1.10	0.00	16
AAK-007	11.46	12.87	54.85	17.43	3.39	16
AAK-008	4.74	5.51	44.33	41.68	3.74	19
AAK-009	31.05	12.82	41.23	14.64	0.26	19

3.2 Total Organic Carbon Results

TOC results for composited core samples are provided in Attachment 3 and summarized in Table 4.

Table 4. Results of TOC Analyses.

Sample Number	Mean TOC [1] (% Dry Wt.)
AAK-001	0.21
AAK-002	0.20
AAK-002A	0.21
AAK-003	0.14
AAK-004	0.205
AAK-005	0.26
AAK-006	0.13
AAK-007	0.20
AAK-008	0.40
AAK-009	0.275

[1]All TOC analyses were performed in duplicate; replicate results are provided in Attachment 1

3.3 Metals Results

Fifteen metals were analyzed. Metals results are provided in Attachment 4. QA/QC results were all within acceptable limits.

3.4 PCB Results

Results of PCB analyses for all field samples and quality control samples are provided in Attachment 5. PCBs were not detected in many of the composited sediment samples above the target detection limit of 1 μg/kg. Surrogate recoveries were all within control limits. The Procedural Blank (PB), Laboratory Control Sample (LCS), Matrix Spike/Matrix, and Matrix Spike Duplicate (MS/MSD) were all within recovery and Relative Percent Difference (RPD) control limits with the exception of one surrogate in the MSD. The Standard Reference Material (SRM) was processed and analyzed with the batch. The percent difference (PD) between the measured value and the certified range was calculated to measure accuracy and all PDs were within the control limits. Note that one sample, AAK-002A was analyzed separately and results are not completed. Results will be included as an addendum to this report when available.

3.5 PAH Results

Results of PAH analyses for all field samples and quality control samples are provided in Attachment 6. High molecular weight PAHs were detected in most composited sediment samples at levels above the Target Detection Limit. Surrogate recoveries were all within control limits. The procedural blank sample was found to be clean and both the procedural blank and the laboratory control samples all had surrogate recoveries within the specified limits. Matrix spike recoveries were generally within the control limits, however, the MSD recoveries were mostly outside of control limits as were the subsequent RPD values between MS and MSD recoveries. Analytical duplicate recoveries were also outside of control limits. These QC exceedences were most likely due to the coarse, non-homogenous nature of these samples as they relate to PAH contamination since precision data for other parameters (grain size, TOC and metals) were acceptable. Note that one sample, AAK-002A was analyzed separately and results are not completed. Results will be included as an addendum to this report when available.

4.0 REFERENCES

Battelle 2001. *Field Survey Report for Deerfield River Feasibility Study Field Sampling and Laboratory Testing for Sediment Samples from Green River, Greenfield, MA.*

Attachment 1

Custody Records

Battelle ... Putting Technology To Work

Chain of Custody

DOA / 03

Proj. No	Proj. Name
G485006-0001	Deerfield River ACOE

SAMPLERS: Signature

ANALYSIS REQUESTED → "NUMBER OF CONTAINERS"

DATE	TIME	BATTELLE ID	CLIENT ID	SAMPLE DESCRIPTION	PEST	PCB	TPH FINGERPRINT	PAH	VOA	TBT	METALS	OTHER	ACIDIFIED	PRESERVED	Total Number of Containers
9/5/01	1710	AAK-001-A		8 oz glass Jar 3/4 full Sediment								X			1
9/5/01	—	AAK-002-A										X			1
9/5/01	09:45	AAK-003-A										X			1
9/5/01	13:36	AAK-004-A										X			1
9/5/01	09:35	AAK-005-A										X			1
9/5/01	13:15	AAK-006-A										X			1
9/5/01	15:55	AAK-007-A										X			1
9/5/01	09:20	AAK-008-A										X			1
9/5/01	11:10	AAK-009-A										X			1

Relinquished by:	Date/Time		Received by:	Date/Time	
[illegible signature]	9/7/01	1515	J. Arsenault Put in upper cold room	9/7/01	1530
Relinquished by:	Date/Time		Received by:	Date/Time	
			[illegible signature]	9/11/01	0915

Comments:

LAB COPY

ATTACHMENT 4a
Battelle Duxbury Operations
Sample Receipt Form

Deerfield SJ 10/24/01

Project Number: ______ Client: ~~MADRA~~
Received by: GDF Date/Time Received: 10/22/01 2:00 PM
No. of Shipping Containers 1

SHIPMENT

Method of Delivery: ______ Commercial Carrier (Air bill No. ______)
✓ Hand Delivered
______ US Mail (RPS No. ______)

COC Forms: ✓ Shipped with samples ______ No forms

Cooler(s)\Box(es) were sealed with: ✓ Tape ______ Custody Seals ______ (Other specify)
Were the seals intact for each shipping container? ✓ Yes ______ No ______ NA
If NO, see Sample Custody Corrective Action Form

SAMPLES

Sample Labels: ✓ Sample labels agree with COC forms
______ Discrepancies (see Sample Custody Corrective Action Form)*

Container Seals: ✓ Tape ______ Custody Seals ______ (Other specify)
✓ Seals intact for each shipping container
______ Seal broken (list impacted samples):

Condition of Samples: ✓ Sample containers intact
______ Sample containers broken/leaking (see Sample Custody Corrective Action Form)*

Temperature upon receipt (°C): 2.2° Temperature blank used ______ Yes ✓ No
(Note: If temperature upon receipt differs from required conditions, list impacted samples):

Samples Acidified? ___ Yes ✓ No ___ Unknown

Initial pH 5 - 9? (Y/N): NA *If no, individual sample adjustments on the Auxiliary Sample Receipt Form.*

Total Residual Chlorine Present? (water) (Y/N): NA
If yes, individual sample adjustments on the Auxiliary Sample Receipt Form.

Head Space <1% in samples for water VOC analysis NA Yes ______ No
Individual sample deviations listed below.

Sample Containers:
Samples returned in PC-grade jars? ___ Yes ✓ No ___ Unknown / Lot No. ______

Storage Location: WALK IN FREEZER BDO IDs Assigned: W8250

Holding Times:	Water -	Sediment -	Tissue -

Additional Comments:

Samples logged in by: [signature] Date/Time: 10/23/01 3:00 PM
* Must also be noted on the C-O-C.

Battelle
. . . Putting Technology To Work

Chain of Custody

Proj. No

Proj. Name: Deerfield River Feasibility Study

SAMPLERS: Signature: Robert M Reynolds

DATE	TIME	BATTELLE ID	CLIENT ID	SAMPLE DESCRIPTION	PEST	PCB	TPH FINGERPRINT	PAH	VOA	TBT	METALS	OTHER	ACIDIFIED	PRESERVED	Total Number of Containers
10/22/01	1007	W8250	DEERFIELD RIVER	Sta. 2A											8

ANALYSIS REQUESTED → "NUMBER OF CONTAINERS"

Relinquished by:	Date/Time		Received by:	Date/Time	
Rob Reynolds	10/22/01	1400	[signature]	10/22/01	2:01pm
Relinquished by:	Date/Time		Received by:	Date/Time	

Comments:

ORIGINAL

BATTELLE Laboratory Sample Login Report

Project # : PENDING *Receive Date :* 10/22/01 2:00:00 PM

Client : MWRA *Logged in By :* JHATCH

Collection Date	*Login Date*	*Lab ID*	*Client Sample ID*	*#Containers*	*Matrix*	*Preservative*	*Storage Location*	*Login Comments*
10/22/01 10:07:00 AM	10/23/01 3:09:42 PM	W8250	DEERFIELD RIVER STA.	8	SOIL/ SED	NONE	WALK IN FREEZER	

Attachment 2

Grain Size
Results and Plots

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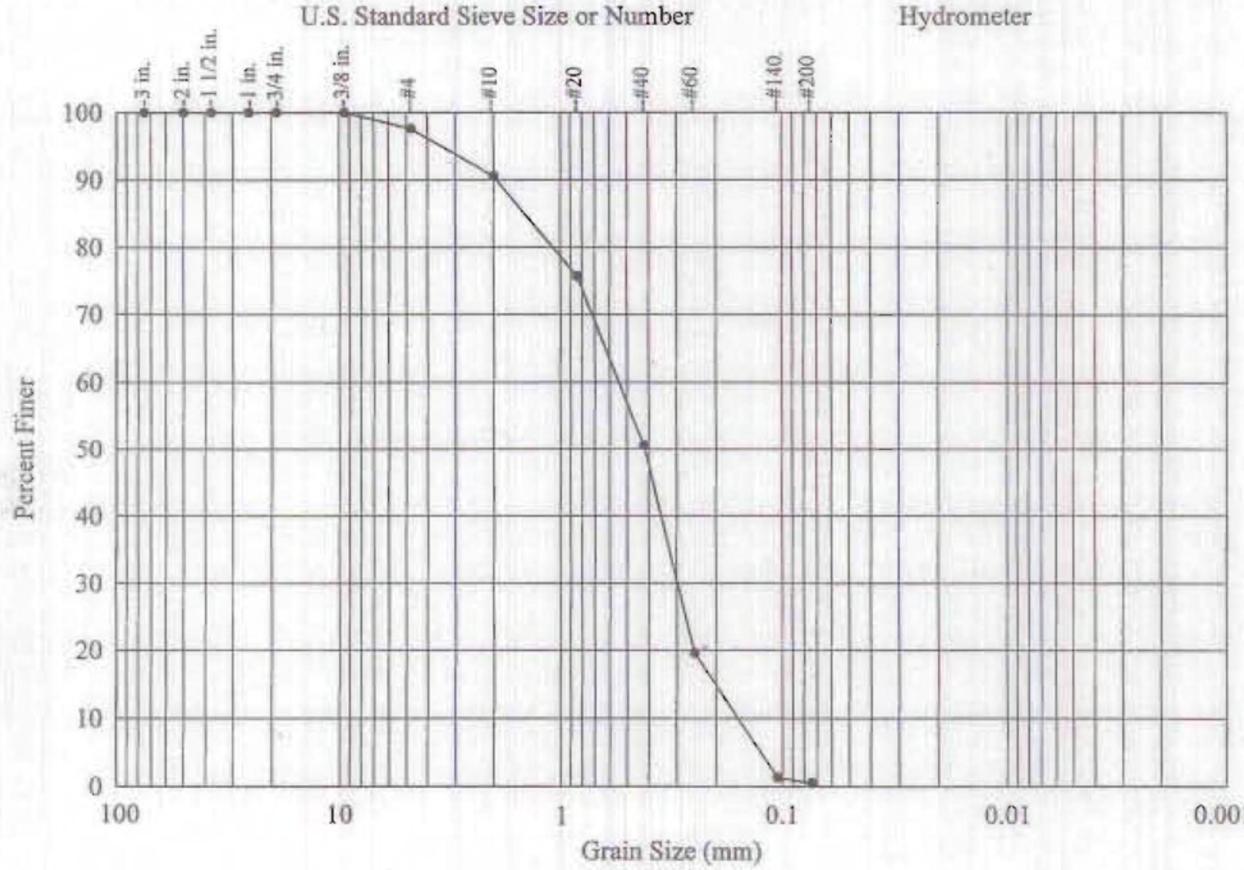

ASTM D422 (Particle-Size Analysis of Soils)

% Cobble >3"	% Gravel <3" - #4	% Sand Coarse #10	% Sand Medium #20-#40	% Sand Fine #60-#200	% Fines Silt/Clay <0.074 mm
0.00	2.40	7.07	39.89	50.17	0.47

Water Cont. (%)	Tot. Solids (%)	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
24	81			1.50	0.55	0.41	0.30	0.19	0.16	1.02	3.44

Material Description	USCS
Poorly-Graded Sand, Dusky Yellowish Brown (10YR2/2)	SP

Project Description		
USACE-New England District Deerfield River	Client P/N:	G487006-0001
	AMS P/N:	2001-03-14
	Client ID:	AAK-001-A
	AMS ID:	9549
AMS, Inc. Project Manager: KSL	Date: -	9/20/01

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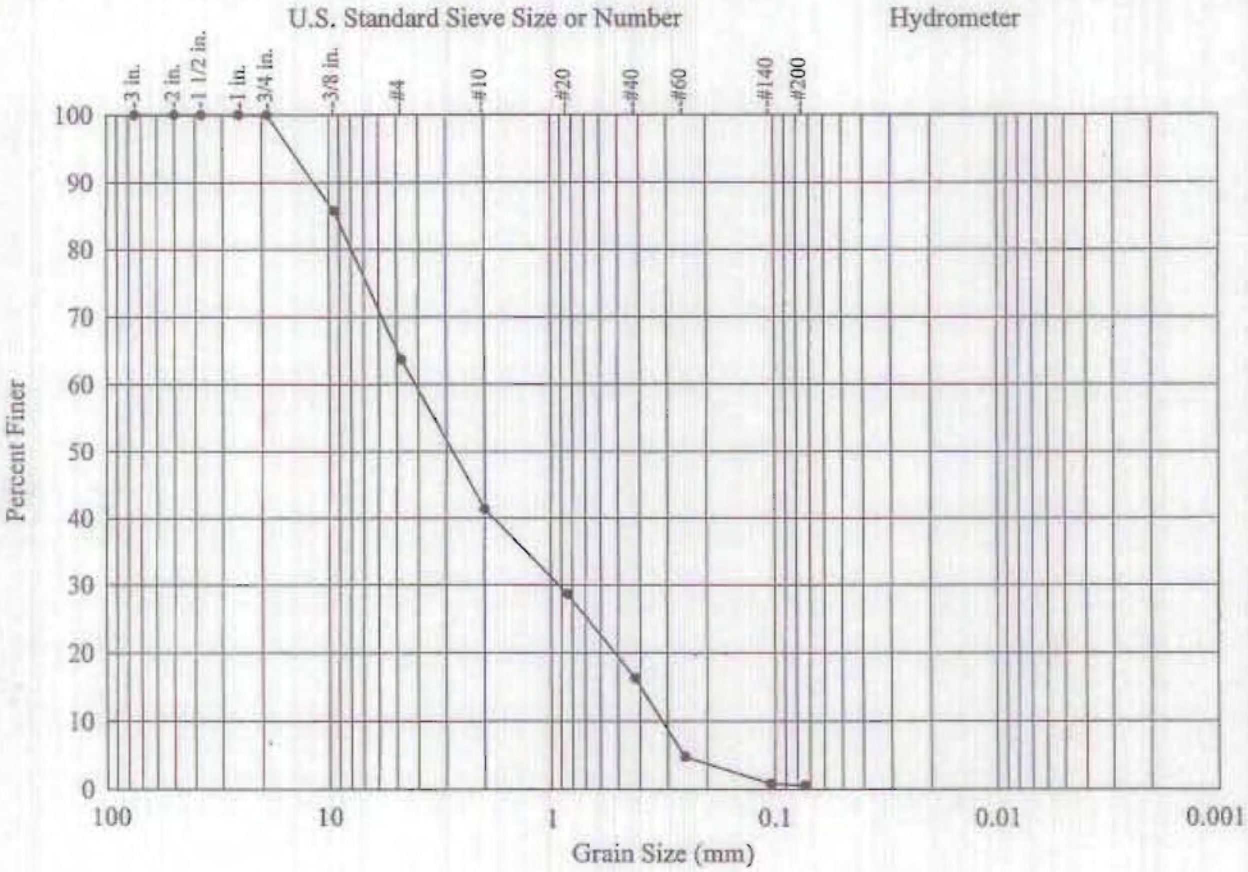

ASTM D422 (Particle-Size Analysis of Soils)

% Cobble >3"	% Gravel <3" - #4	% Sand Coarse #10	% Sand Medium #20-#40	% Sand Fine #60-#200	% Fines Silt/Clay <0.074 mm
0.00	36.34	22.33	25.09	15.70	0.54

Water Cont. (%)	Tot. Solids (%)	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
18	85			9.0	4.1	2.9	0.91	0.38	0.31	0.65	13.23

Material Description	USCS
Poorly-Graded Sand With Gravel, Dusky Yellowish Brown (10YR2/2)	SP

Project Description		
USACE-New England District Deerfield River	Client P/N:	G487006-0001
	AMS P/N:	2001-03-14
	Client ID:	AAK-002-A
	AMS ID:	9550
AMS, Inc. Project Manager:	Date:	9/20/01

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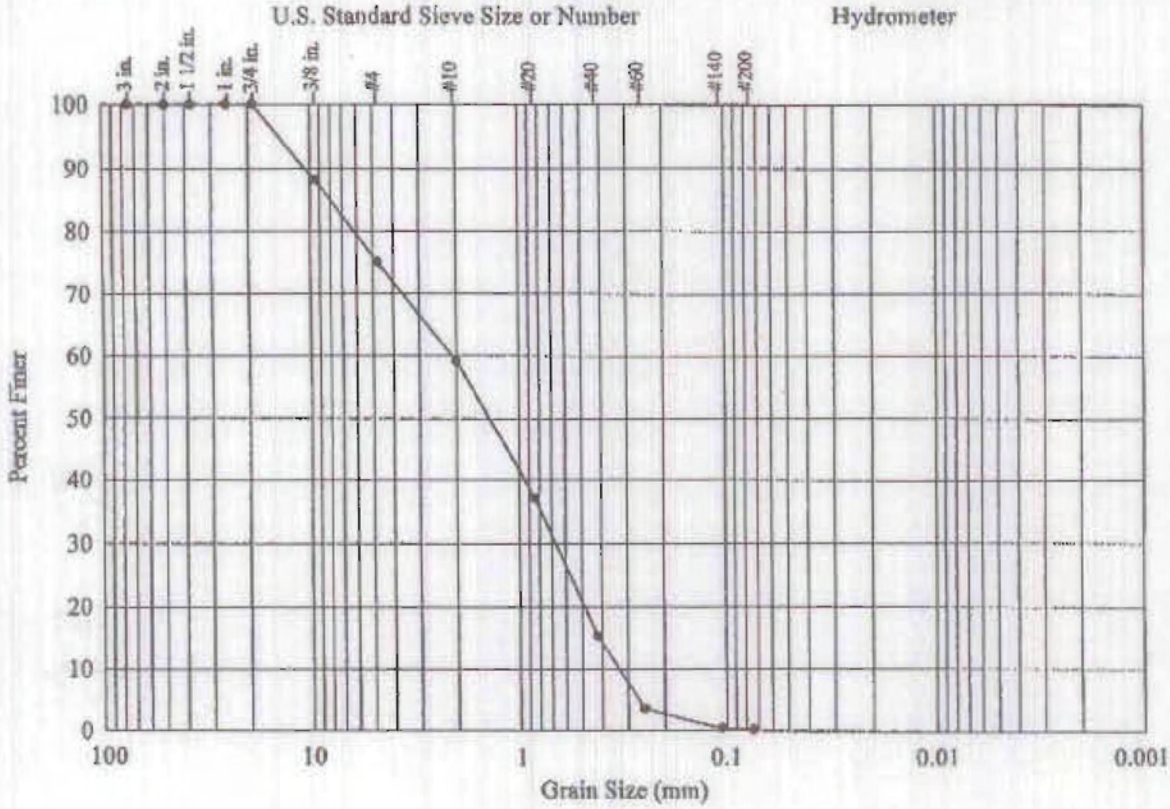

ASTM D422 (Particle-Size Analysis of Soils)

% Cobble >3"	% Gravel <3" - #4	% Sand Coarse #10	% Sand Medium #20-#40	% Sand Fine #60-#200	% Fines Silt/Clay <0.074 mm
0.00	24.85	16.00	43.81	15.14	0.21

Water Cont. (%)	Tot. Solids (%)	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
43	70			8.0	2.2	1.5	0.69	0.40	0.33	0.66	6.67

Material Description	USCS
Poorly-Graded Sand With Gravel, Dusky Yellowish Brown (10YR2/2) to Very Pale Orange (10YR8/2)	SP

Project Description		
USACE-New England District Deerfield River	Client P/N:	G487006-0001
	AMS P/N:	2001-03-14
	Client ID:	AAK-002A-A
	AMS ID:	9586
AMS, Inc. Project Manager: KS	Date:	10/5/01

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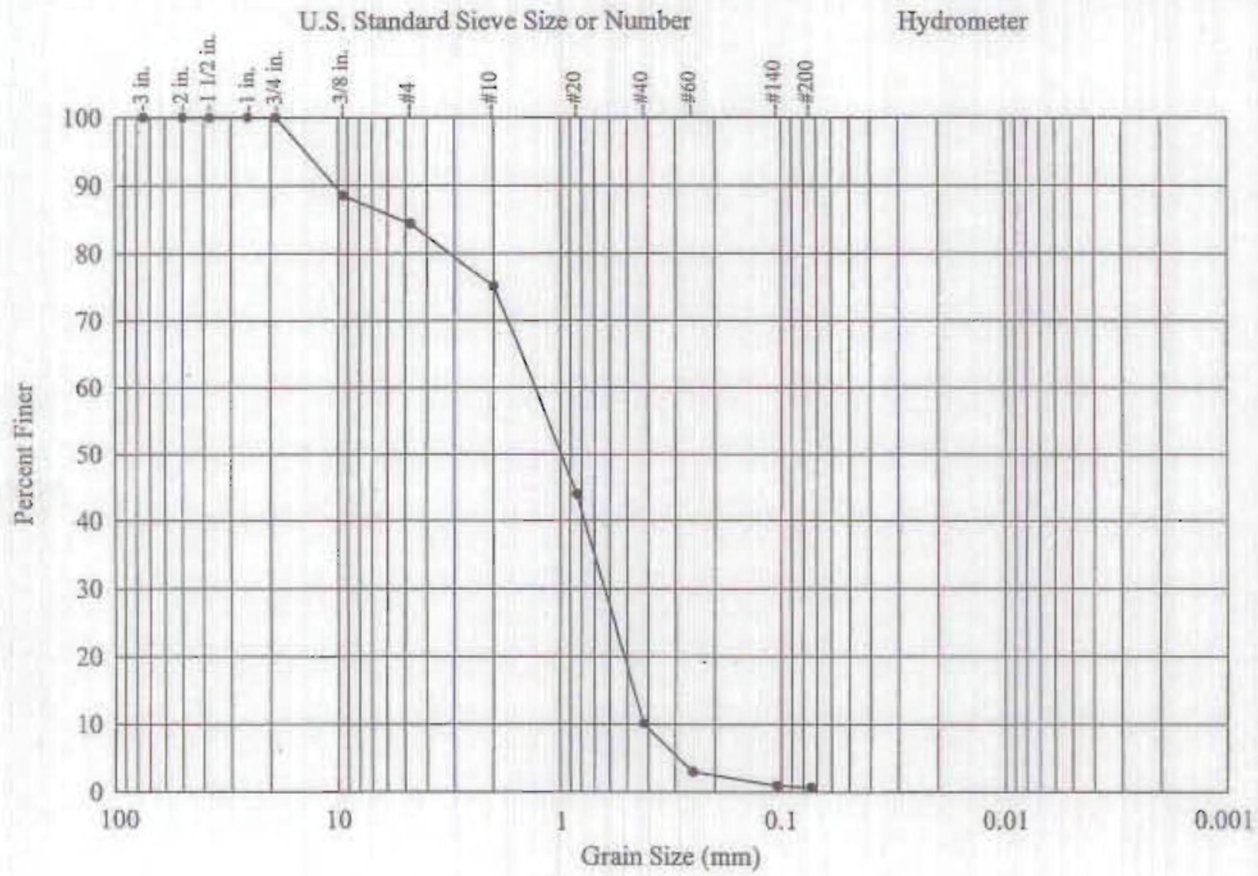

ASTM D422 (Particle-Size Analysis of Soils)

% Cobble >3"	% Gravel <3" - #4	% Sand Coarse #10		% Sand Medium #20-#40		% Sand Fine #60-#200		% Fines Silt/Clay <0.074 mm			
0.00	15.59	9.25		65.06		9.48		0.62			
Water Cont. (%)	Tot. Solids (%)	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
18	85			5.0	1.5	1.0	0.61	0.46	0.41	0.61	3.66

Material Description	USCS
Poorly-Graded Sand With Gravel, Dusky Yellowish Brown (10YR2/2)	SP

Project Description		
USACE-New England District Deerfield River	Client P/N:	G487006-0001
	AMS P/N:	2001-03-14
	Client ID:	AAK-003-A
	AMS ID:	9551
AMS, Inc. Project Manager: KSh	Date:	9/20/01

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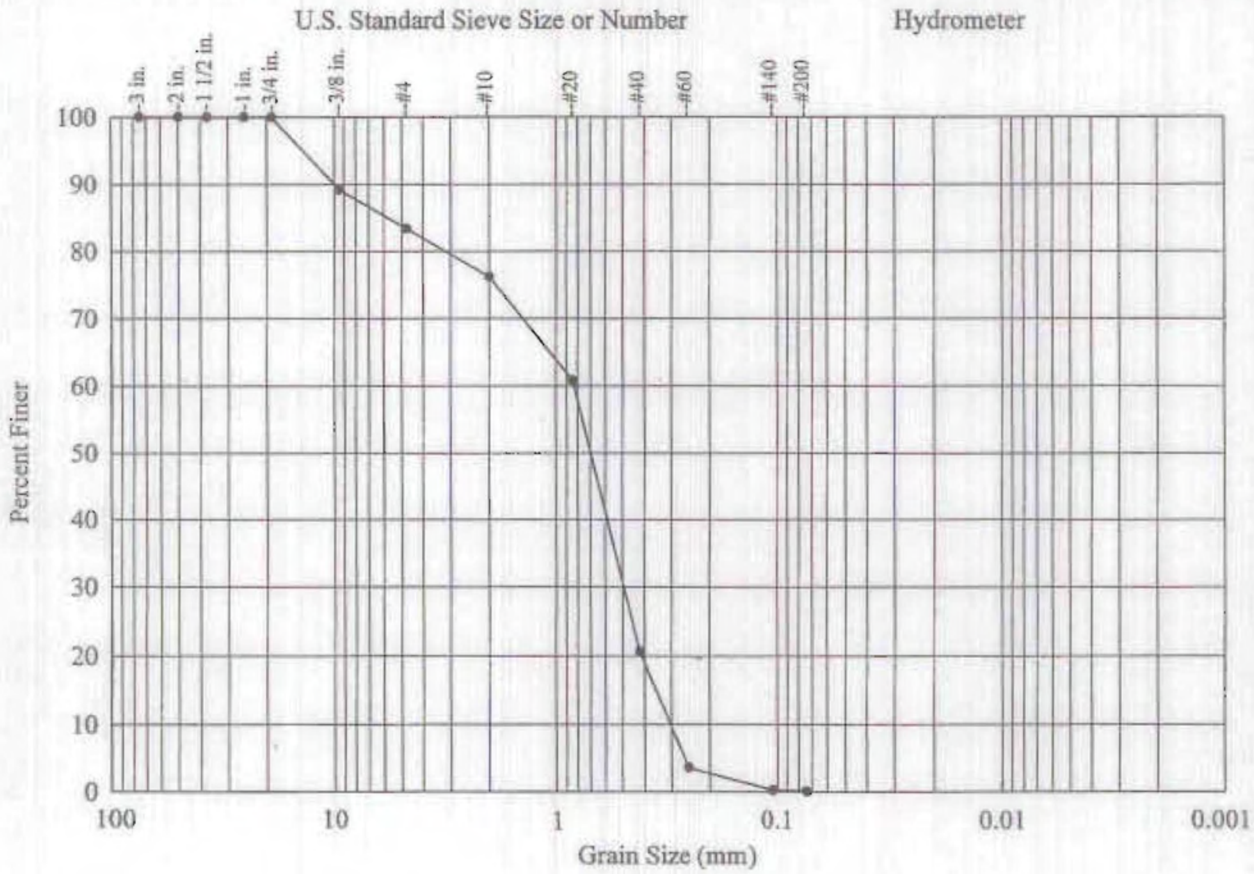

ASTM D422 (Particle-Size Analysis of Soils)

% Cobble >3"	% Gravel <3" - #4	% Sand Coarse #10	% Sand Medium #20-#40	% Sand Fine #60-#200	% Fines Silt/Clay <0.074 mm
0.00	16.65	7.13	55.63	20.56	0.03

Water Cont. (%)	Tot. Solids (%)	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
20	83			5.5	0.8	0.7	0.50	0.35	0.30	1.03	2.70

Material Description	USCS
Poorly-Graded Sand With Gravel, Brownish Gray (5YR4/1) to Dusky Yellowish Brown (10YR2/2)	SP

Project Description		
USACE-New England District Deerfield River	Client P/N:	G487006-0001
	AMS P/N:	2001-03-14
	Client ID:	AAK-004-A
	AMS ID:	9552
AMS, Inc. Project Manager: KSD	Date:	9/20/01

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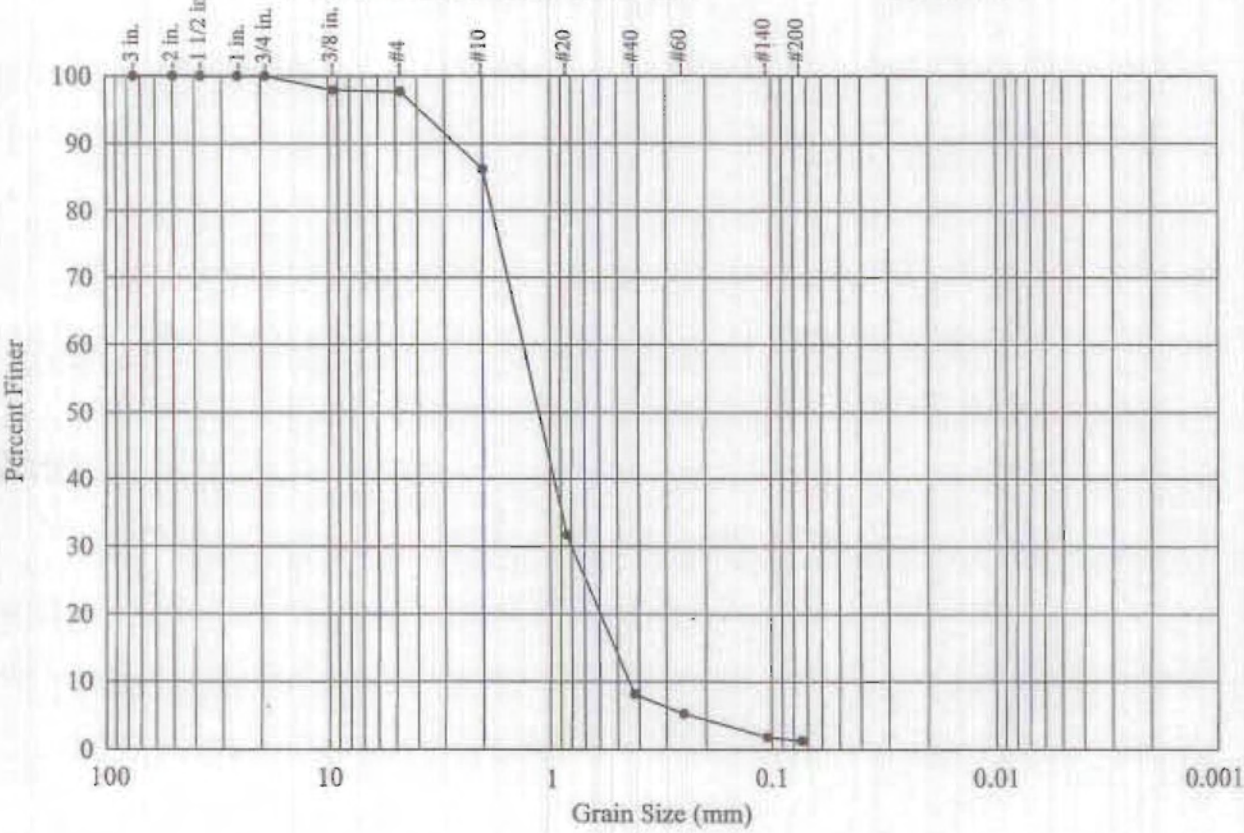

ASTM D422 (Particle-Size Analysis of Soils)

% Cobble >3"	% Gravel <3" - #4	% Sand Coarse #10	% Sand Medium #20-#40	% Sand Fine #60-#200	% Fines Silt/Clay <0.074 mm
0.00	2.29	11.52	78.08	6.88	1.23

Water Cont. (%)	Tot. Solids (%)	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
25	80			1.9	1.4	1.2	0.80	0.50	0.45	1.02	3.11

Material Description	USCS
Poorly-Graded Sand, Brownish Gray (5YR4/1) to Pinkish Gray (5YR8/1) and Pale Orange (10YR8/2)	SP

Project Description		
USACE-New England District Deerfield River	Client P/N:	G487006-0001
	AMS P/N:	2001-03-14
	Client ID:	AAK-005-A
	AMS ID:	9553
AMS, Inc. Project Manager:	Date:	9/20/01

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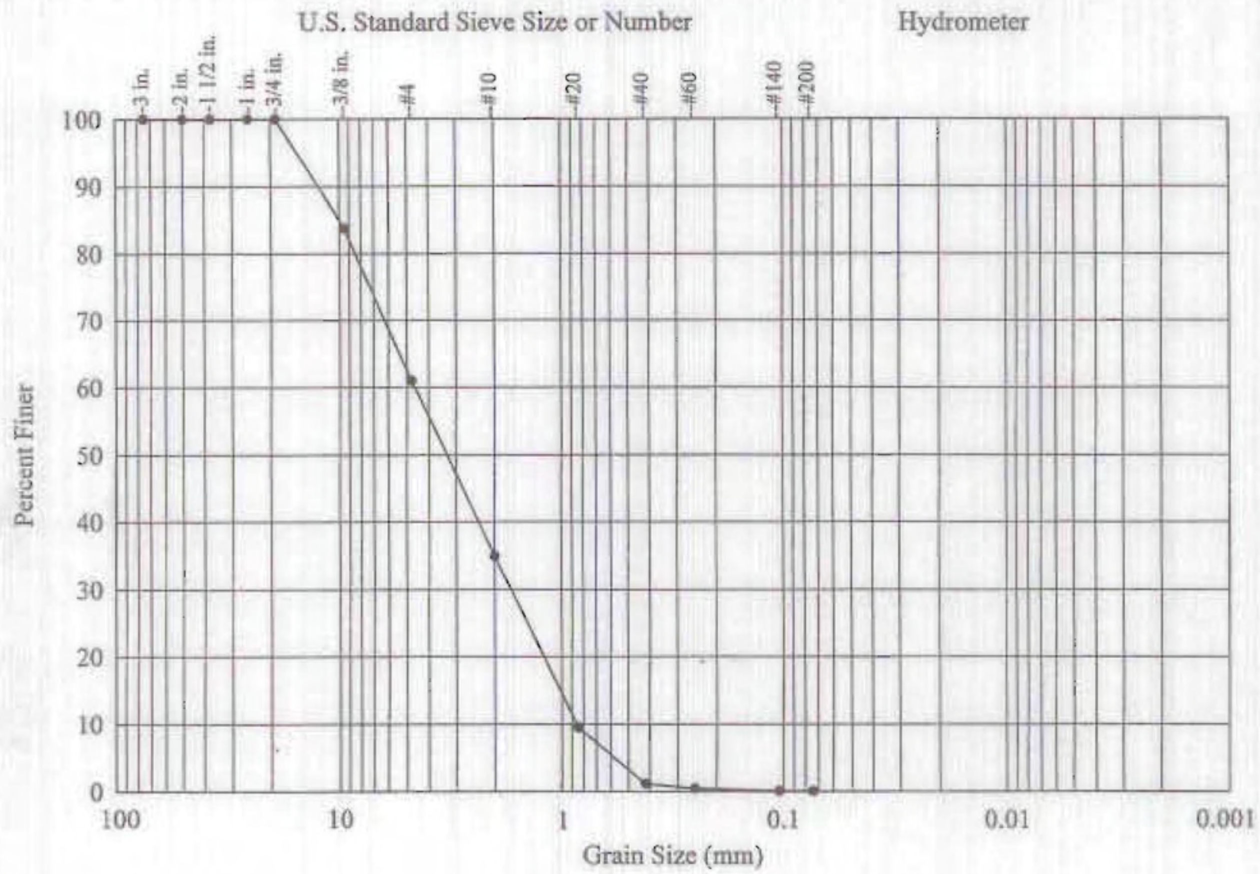

ASTM D422 (Particle-Size Analysis of Soils)

% Cobble >3"	% Gravel <3" - #4	% Sand						% Fines			
		Coarse #10		Medium #20-#40		Fine #60-#200		Silt/Clay <0.074 mm			
0.00	39.05	26.03		33.82		1.10		0.00			
Water Cont. (%)	Tot. Solids (%)	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
16	86			10.0	4.6	3.3	1.70	1.00	0.89	0.71	5.17

Material Description	USCS
Poorly-Graded Sand with Gravel, Dusky Yellowish Brown (10YR2/2)	SP

Project Description		
USACE-New England District Deerfield River	Client P/N:	G487006-0001
	AMS P/N:	2001-03-14
	Client ID:	AAK-006-A
	AMS ID:	9554
AMS, Inc. Project Manager: KS	Date:	9/20/01

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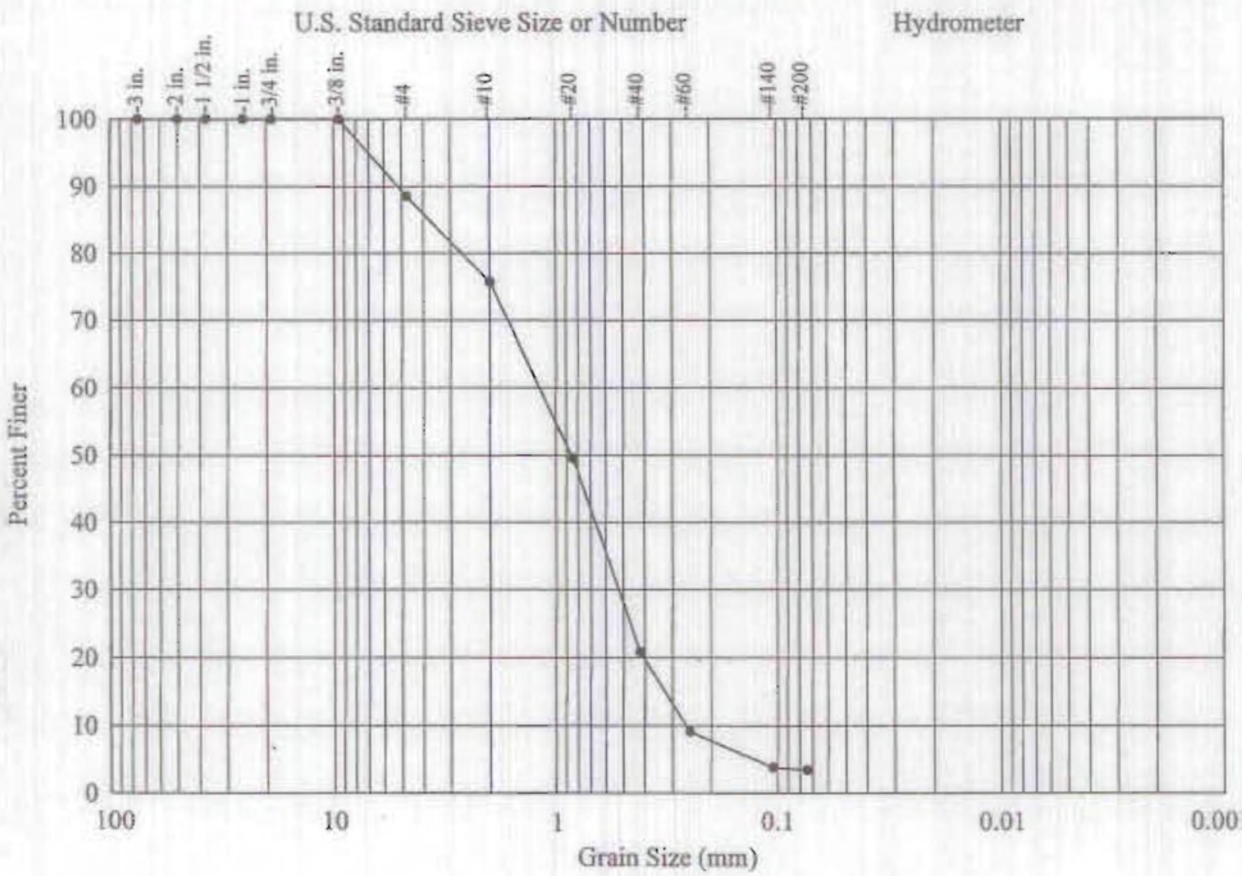

ASTM D422 (Particle-Size Analysis of Soils)

% Cobble >3"	% Gravel <3" - #4	% Sand Coarse #10		% Sand Medium #20-#40		% Sand Fine #60-#200		% Fines Silt/Clay <0.074 mm			
0.00	11.46	12.87		54.85		17.43		3.39			
Water Cont. (%)	Tot. Solids (%)	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
16	86			3.5	1.3	0.9	0.51	0.31	0.26	0.77	5.00

Material Description	USCS
Poorly-Graded Sand, Light Olive Gray (5Y6/1) to Light Brown (5YR5/6), Small Quantity of Organic Debris (Acorns)	SP

Project Description		
USACE-New England District Deerfield River	Client P/N:	G487006-0001
	AMS P/N:	2001-03-14
	Client ID:	AAK-007-A
	AMS ID:	9555
AMS, Inc. Project Manager:	Date:	9/20/01

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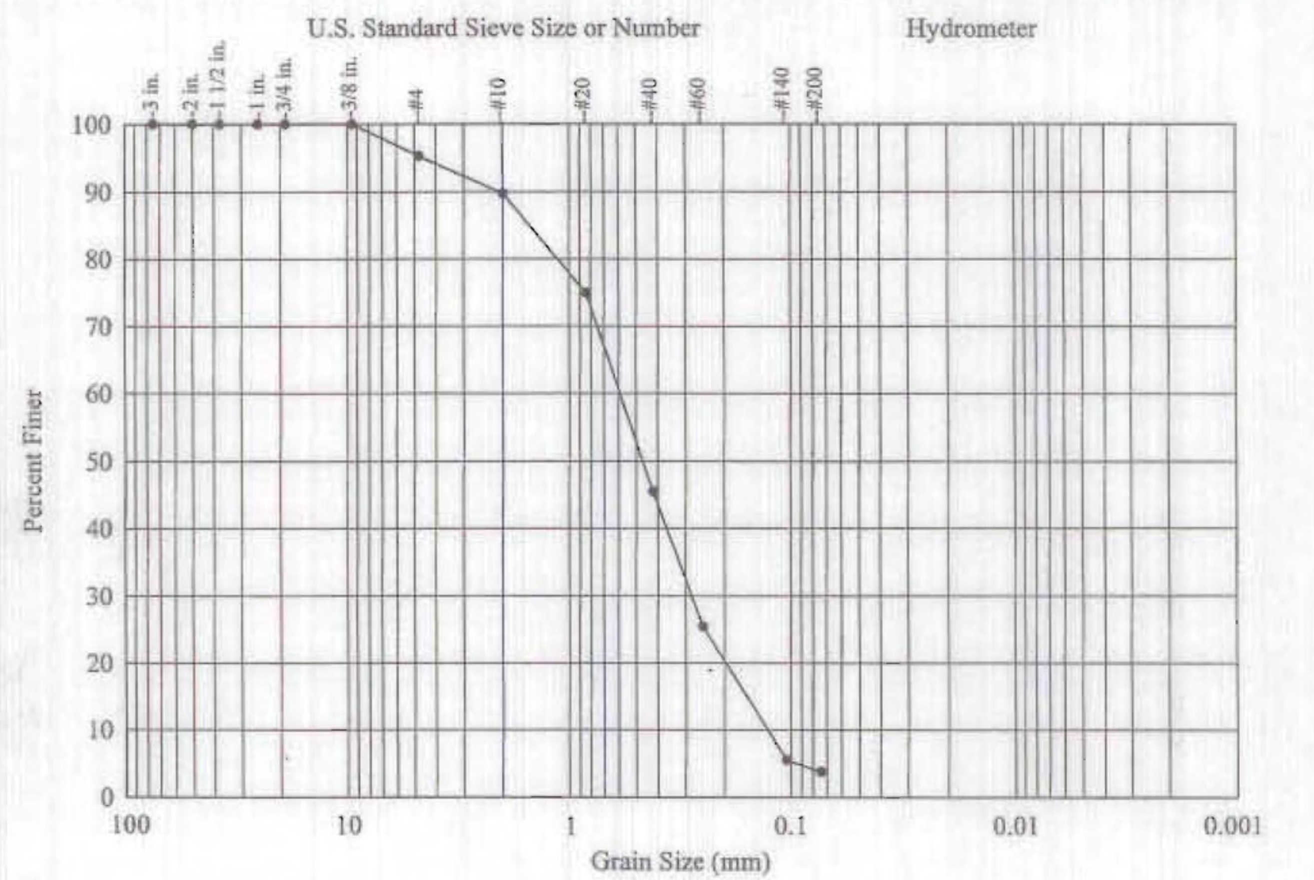

ASTM D422 (Particle-Size Analysis of Soils)

% Cobble >3"	% Gravel <3" - #4	% Sand: Coarse #10		% Sand: Medium #20-#40		% Sand: Fine #60-#200		% Fines: Silt/Clay <0.074 mm			
0.00	4.74	5.51		44.33		41.68		3.74			
Water Cont. (%)	Tot. Solids (%)	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
19	84			1.5	0.60	0.48	0.28	0.16	0.14	0.93	4.29

Material Description	USCS
Poorly-Graded Sand, Brownish Gray (5YR4/1) to Darkish Yellowish Brown (10YR4/2), Small Quantity of Organic Debris (Twigs)	SP

Project Description		
USACE-New England District Deerfield River	Client P/N:	G487006-0001
	AMS P/N:	2001-03-14
	Client ID:	AAK-008-A
	AMS ID:	9556
AMS, Inc. Project Manager:	Date:	9/20/01

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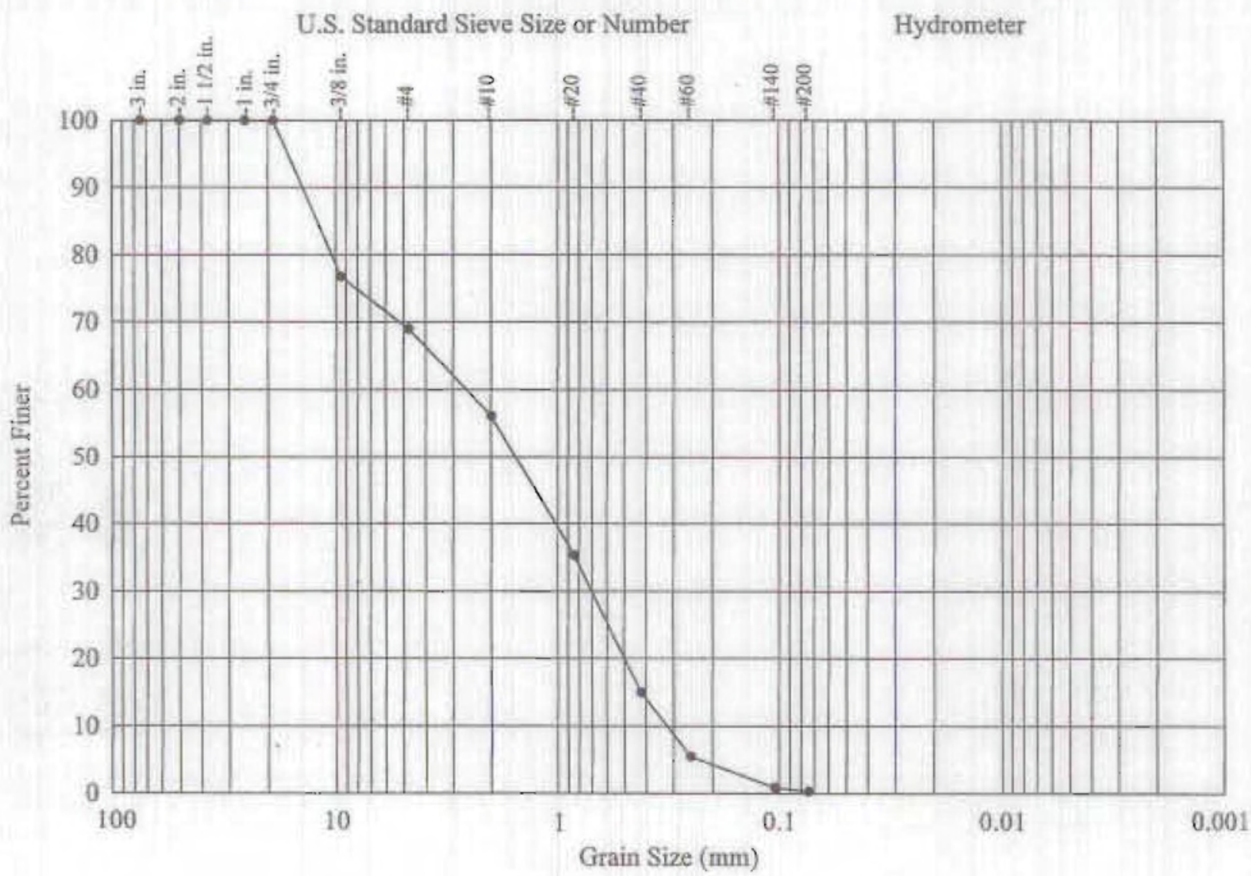

ASTM D422 (Particle-Size Analysis of Soils)

		% Sand			% Fines
% Cobble >3"	% Gravel <3" - #4	Coarse #10	Medium #20-#40	Fine #60-#200	Silt/Clay <0.074 mm
0.00	31.05	12.82	41.23	14.64	0.26

Water Cont. (%)	Tot. Solids (%)	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
19	84			13.0	2.7	1.6	0.70	0.40	0.31	0.59	8.71

Material Description	USCS
Poorly-Graded Sand With Gravel, Dusky Yellowish Brown (10YR2/2) to Very Pale Orange (10YR8/2)	SP

Project Description		
USACE-New England District Deerfield River	Client P/N:	G487006-0001
	AMS P/N:	2001-03-14
	Client ID:	AAK-009-A
	AMS ID:	9557
AMS, Inc. Project Manager:	Date:	9/20/01

Applied Marine Sciences, Inc.

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AMS QUALITY CONTROL REPORT

Project Number: G487006-0001

Project Title: USACE New England District. Deerfield River

Client: Battelle-Duxbury Operations

Battelle Sample ID: AAK-004-A

AMS Sample ID: 9552

AMS Project Number: 2001-03-14

Date Sampled: 9/5/01

Date Received: 9/11/01

Date Analyzed: 9/13/01

Matrix: Soil

Method: ASTM D422

Replicate Analysis

Size Class	U.S. Standard Sieve Size	Diameter (mm)	Sample Result %	Duplicate Result %	RPD %	QC Limits % RPD
Gravel	No. 4	>4.75	16.65	13.90	18.00	<25
Coarse Sand	No. 10	2.00	7.13	6.87	3.71	<25
Medium Sand	No. 40	0.42	55.63	58.18	4.48	<25
Fine Sand	No. 200	0.074	20.56	21.02	2.21	<25
Silt/Clay		<0.074	0.03	0.03	0.00	<25

Samples in Batch (AMS ID): 9549 9550 9551 9552 9553 9554 9555 9556 9557

KSD

AMS, Inc. Project Manager

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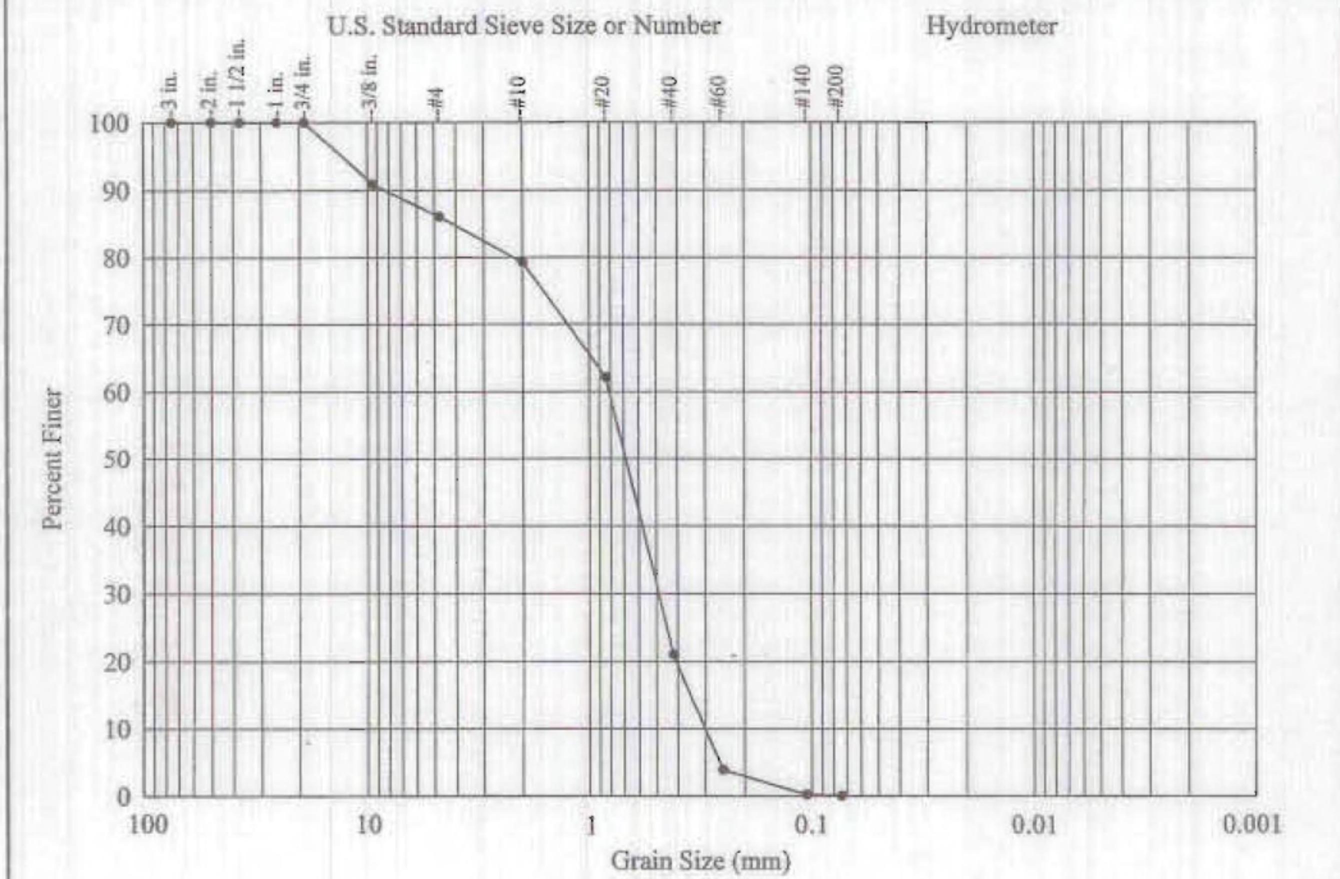

ASTM D422 (Particle-Size Analysis of Soils)

		% Sand						% Fines			
% Cobble >3"	% Gravel <3" - #4	Coarse #10		Medium #20-#40		Fine #60-#200		Silt/Clay <0.074 mm			
0.00	13.90	6.87		58.18		21.02		0.03			
Water Cont. (%)	Tot. Solids (%)	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
20	83			5.5	0.8	0.7	0.50	0.35	0.30	1.03	2.70

Material Description	USCS
Poorly-Graded Sand, Brownish Gray (5YR4/1) to Dusky Yellowish Brown (10YR2/2)	SP

Project Description		
USACE-New England District Deerfield River	Client P/N:	G487006-0001
	AMS P/N:	2001-03-14
	Client ID:	AAK-004-A
	AMS ID:	9552-2
AMS, Inc. Project Manager: KS	Date: -	9/20/01

Attachment 3

Total Organic Carbon Results

Applied Marine Sciences, Inc.

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Project Number: G487006-0001
Project Title: USACE NAE-Deerfield River
Client: Battelle-Duxbury Operations
Client Samp ID: AAK-001-A
AMS Samp ID: 9549

AMS Project Number: 2001-03-14
Date Sampled: 9/5/01
Date Received: 9/11/01
Matrix: Soil

Total Organic Carbon (EPA SW9060)

Result	Duplicate	RPD	MDL	Unit	Date Analyzed
0.22	0.20	9.52	0.01	%	9/20/01

Quality Assurance: These analyses were performed in accordance with EPA guidelines for quality assurance.

AMS, Inc. Project Manager

Applied Marine Sciences, Inc.

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Project Number: G487006-0001
Project Title: USACE NAE-Deerfield River
Client: Battelle-Duxbury Operations
Client Samp ID: AAK-002-A
AMS Samp ID: 9550

AMS Project Number: 2001-03-14
Date Sampled: 9/6/01
Date Received: 9/11/01
Matrix: Soil

Total Organic Carbon (EPA SW9060)

Result	Duplicate	RPD	MDL	Unit	Date Analyzed
0.20	0.20	0.00	0.01	%	9/20/01

Quality Assurance: These analyses were performed in accordance with EPA guidelines for quality assurance.

KSB

AMS, Inc. Project Manager

Applied Marine Sciences, Inc.

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Project Number: G487006-0001
Project Title: USACE NAE-Deerfield River
Client: Battelle-Duxbury Operations
Client Samp ID: AAK-002A-A
AMS Samp ID: 9586

AMS Project Number: 2001-03-14
Date Sampled: N/A
Date Received: 9/18/01
Matrix: Soil

Total Organic Carbon (EPA SW9060)

Result	Duplicate	RPD	MDL	Unit	Date Analyzed
0.22	0.20	9.52	0.01	%	9/20/01

Quality Assurance: These analyses were performed in accordance with EPA guidelines for quality assurance.

KSD

AMS, Inc. Project Manager

Applied Marine Sciences, Inc.

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Project Number: G487006-0001
Project Title: USACE NAE-Deerfield River
Client: Battelle-Duxbury Operations
Client Samp ID: AAK-003-A
AMS Samp ID: 9551

AMS Project Number: 2001-03-14
Date Sampled: 9/6/01
Date Received: 9/11/01
Matrix: Soil

Total Organic Carbon (EPA SW9060)

Result	Duplicate	RPD	MDL	Unit	Date Analyzed
0.15	0.13	14.29	0.01	%	9/20/01

Quality Assurance: These analyses were performed in accordance with EPA guidelines for quality assurance.

KSL

AMS, Inc. Project Manager

Applied Marine Sciences, Inc.

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Project Number: G487006-0001
Project Title: USACE NAE-Deerfield River
Client: Battelle-Duxbury Operations
Client Samp ID: AAK-004-A
AMS Samp ID: 9552

AMS Project Number: 2001-03-14
Date Sampled: 9/5/01
Date Received: 9/11/01
Matrix: Soil

Total Organic Carbon (EPA SW9060)

Result	Duplicate	RPD	MDL	Unit	Date Analyzed
0.20	0.21	4.88	0.01	%	9/20/01

Quality Assurance: These analyses were performed in accordance with EPA guidelines for quality assurance.

AMS, Inc. Project Manager

Applied Marine Sciences, Inc.

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Project Number: G487006-0001
Project Title: USACE NAE-Deerfield River
Client: Battelle-Duxbury Operations
Client Samp ID: AAK-005-A
AMS Samp ID: 9553

AMS Project Number: 2001-03-14
Date Sampled: 9/5/01
Date Received: 9/11/01
Matrix: Soil

Total Organic Carbon (EPA SW9060)

Result	Duplicate	RPD	MDL	Unit	Date Analyzed
0.27	0.25	7.69	0.01	%	9/20/01

Quality Assurance: These analyses were performed in accordance with EPA guidelines for quality assurance.

AMS, Inc. Project Manager

Applied Marine Sciences, Inc.

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Project Number: G487006-0001
Project Title: USACE NAE-Deerfield River
Client: Battelle-Duxbury Operations
Client Samp ID: AAK-006-A
AMS Samp ID: 9554

AMS Project Number: 2001-03-14
Date Sampled: 9/5/01
Date Received: 9/11/01
Matrix: Soil

Total Organic Carbon (EPA SW9060)

Result	Duplicate	RPD	MDL	Unit	Date Analyzed
0.13	0.13	0.00	0.01	%	9/20/01

Quality Assurance: These analyses were performed in accordance with EPA guidelines for quality assurance.

AMS, Inc. Project Manager

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Project Number: G487006-0001
Project Title: USACE NAE-Deerfield River
Client: Battelle-Duxbury Operations
Client Samp ID: AAK-007-A
AMS Samp ID: 9555

AMS Project Number: 2001-03-14
Date Sampled: 9/5/01
Date Received: 9/11/01
Matrix: Soil

Total Organic Carbon (EPA SW9060)

Result	Duplicate	RPD	MDL	Unit	Date Analyzed
0.19	0.21	10.00	0.01	%	9/20/01

Quality Assurance: These analyses were performed in accordance with EPA guidelines for quality assurance.

KSL

AMS, Inc. Project Manager

Applied Marine Sciences, Inc.

502 N. Highway 3, Suite B • League City, TX 77573 • (281) 554-7272 • Fax (281) 554-6356

Project Number: G487006-0001
Project Title: USACE NAE-Deerfield River
Client: Battelle-Duxbury Operations
Client Samp ID: AAK-008-A
AMS Samp ID: 9556

AMS Project Number: 2001-03-14
Date Sampled: 9/5/01
Date Received: 9/11/01
Matrix: Soil

Total Organic Carbon (EPA SW9060)

Result	Duplicate	RPD	MDL	Unit	Date Analyzed
0.41	0.39	5.00	0.01	%	9/20/01

Quality Assurance: These analyses were performed in accordance with EPA guidelines for quality assurance.

KSD

AMS, Inc. Project Manager

Applied Marine Sciences, Inc.

502 N. Highway 3, Suite B • League City, TX 77573 • (281) 554-7272 • Fax (281) 554-6356

Project Number: G487006-0001
Project Title: USACE NAE-Deerfield River
Client: Battelle-Duxbury Operations
Client Samp ID: AAK-009-A
AMS Samp ID: 9557

AMS Project Number: 2001-03-14
Date Sampled: 9/5/01
Date Received: 9/11/01
Matrix: Soil

Total Organic Carbon (EPA SW9060)

Result	Duplicate	RPD	MDL	Unit	Date Analyzed
0.28	0.27	3.64	0.01	%	9/20/01

Quality Assurance: These analyses were performed in accordance with EPA guidelines for quality assurance.

AMS, Inc. Project Manager

Applied Marine Sciences, Inc.

502 N. Highway 3, Suite B • League City, TX 77573 • (281) 554-7272 • Fax (281) 554-6356

Quality Control Report

Project No.: G487006-0001
Project Title: USACE NAE
Deerfield River
Client: Battelle-Duxbury Operations

AMS Project No.: 2001-03-14
Date Received: 9/11/01
Date Analyzed: 9/20/01
Matrix: Soil
Methods: EPA SW9060

Continuing Calibration Data

AMS Sample ID	Parameter	SRM Result %	SRM Theoretical %	RPD %	QC Limits % RPD
CC01	TOC	4.98	4.80	3.68	<5

TOC Method Blank

AMS Sample ID	Weight (g)	Result ($\mu g\ CO_2$)	TOC (%)	TDL (%)
CB01	0.6279	19.5	ND	0.01

Samples in Batch (AMS ID): 9549 9551 9553 9555 9557
9550 9552 9554 9556

Quality Assurance: These analyses were performed in accordance with EPA guidelines for quality assurance.

AMS, Inc. Project Manager

Attachment 4

Metals Results

QA/QC NARRATIVE

PROJECT: Deerfield River
PARAMETER: Metals
LABORATORY: Battelle Marine Sciences Laboratory, Sequim, Washington
MATRIX: Sediment

SAMPLE CUSTODY AND PROCESSING:

Ten sediment samples for metals analysis were received on 9/18/01. All samples were received in good condition (i.e., no sample containers were broken). Samples were assigned a Battelle Central File (CF) identification number (1714) and were entered into Battelle's log-in system.

The following lists information on sample receipt and processing activities:

Lab Sample IDs:	1711-1 through –10
Description:	Sediment samples
Sample collection date	9/5/01 to 9/6/01
Laboratory arrival date	9/18/01
Cooler temp. on arrival	5.4°C
Digestion ($HNO_3/H_2O_2/HF$, wet wt. basis)	10/7/01
ICP-AES analysis (Ag, Ba, Cr. Cu, Ni, V, Zn)	10/10/01
CVAA analysis (Hg)	10/9/01
ICP-MS analysis (As, Be, Cd, Pb, Sb, Tl)	10/15/01
FIAS analysis - Se	10/15/01

DATA QUALITY OBJECTIVES:

Analyte	Analytical Method	Range of Recovery	SRM Accuracy	Relative Precision	Reporting Limits (µg/g dry wt.)	Achieved Detection Limits (µg/g dry wt.)
Ag	ICP-AES	70-130%	± 20%	≤ 30%	0.1	0.1
As	ICP-MS	70-130%	± 20%	≤ 30%	0.5	0.07
Ba	ICP-AES	70-130%	± 20%	≤ 30%	1.0	0.009
Be	ICP-MS	70-130%	± 20%	≤ 30%	1.0	0.02
Cd	ICP-MS	70-130%	± 20%	≤ 30%	0.1	0.02
Cr	ICP-AES	70-130%	± 20%	≤ 30%	1.0	0.3
Cu	ICP-AES	70-130%	± 20%	≤ 30%	1.0	0.1
Hg	CVAA	70-130%	± 20%	≤ 30%	0.02	0.002
Ni	ICP-AES	70-130%	± 20%	≤ 30%	1.0	0.6
Pb	ICP-MS	70-130%	± 20%	≤ 30%	1.0	0.2
Sb	ICP-MS	70-130%	± 20%	≤ 30%	1.0	0.03
Se	FIAS	70-130%	± 20%	≤ 30%	0.1	0.033
Tl	ICP-MS	70-130%	± 20%	≤ 30%	0.1	0.06
V	ICP-AES	70-130%	± 20%	≤ 30%	1.0	0.2
Zn	ICP-AES	70-130%	± 20%	≤ 30%	1.0	0.1

METHODS:

Fifteen metals were analyzed: silver (Ag), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr) copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), antimony (Sb), selenium (Se), thallium (Tl), vanadium (V), and zinc (Zn). Sediment samples were digested using aqua regia according to Battelle SOP MSL-I-006, *Mixed Acid Sediment Digestion.* An approximately 500-mg (dry weight) aliquot of each sample was combined with nitric and hydrochloric acids (aqua regia) in a Teflon bomb and heated in an oven at 130ºC (±10ºC) overnight. After heating and cooling, deionized water was added to the sediment digestate to achieve analysis volume, and the digestates were submitted for analysis.

Sample digestates were analyzed by inductively coupled plasma-atomic emission spectrometry (ICP-AES) following Battelle SOP MSL-I-027, *Determination of Metals in Aqueous and Digestate Samples by ICP/AES.* Results of analysis for Ag, Ba, Cr, Cu, Ni, V, and Zn.

Sample digestates were analyzed using inductively coupled plasma-mass spectrometry (ICP-MS) according to Battelle SOP MSL-I-022, *Determination of Elements in Aqueous and Digestate Samples by ICP/MS.* Results of analysis for As, Be, Cd, Pb, Sb, and Tl were reported.

Selenium was analyzed by flow- injection atomic spectroscopy (FIAS) following a modification of SW846 Methods 7062 and 7742 instead of ICP/MS or ICP/AES as it is more sensitive for this metal and allowed us to achieve the detection limit required.

Hg was analyzed using cold-vapor atomic absorption spectroscopy (CVAA) according to Battelle SOP MSL-I-016, *Total Mercury in Tissues and Sediments by Cold Vapor Atomic Absorption.*

All results were reported in units of µg/g on a dry-weight basis.

HOLDING TIMES: The recommended holding times for metals analyses are 28 days from sample collection for Hg analysis and 6 months for analysis of all other metals. Sediment samples were analyzed for Hg 27 days from sample collection. Sediment samples were analyzed for all other metals within 6 months of collection.

DETECTION LIMITS: Analytical results were reported to client-specified target detection limits. Laboratory-achieved detection limits were less than or equal to target detection limits for all metals.

METHOD BLANKS: A method blank was analyzed with the set of sediment sample digestions. All metals were undetected in the blank.

LABORATORY CONTROL SAMPLE/BLANK SPIKE ACCURACY: A laboratory control sample (LCS) or blank spike was analyzed with the set of sample digestions. The LCS was spiked at three concentrations: 1 µg/g for Hg; 10 µg/g for Ag, As, Be, Cd, Cu, Sb, Se, Tl, and V; and 100 µg/g for Ba, Cr, Ni, Pb, and Zn. LCS recoveries among all metals analyzed were within the QC acceptance criteria of 70% to 130%.

MATRIX SPIKE/MATRIX SPIKE DUPLICATE ACCURACY AND PRECISION: One sediment sample was selected and spiked in duplicate at three concentrations: 1 µg/g for Hg; 10 µg/g for Ag, As, Be, Cd, Cu, Sb, Se, Tl, and V; and 100 µg/g for Ba, Cr, Ni, Pb, and Zn. Matrix spike recoveries for all metals analyzed were within QC acceptance criteria of 70%-130% recovery with the exception of V in the MS and MSD. However, the native concentration of V in the sample selected for spiking was too high relative to the spike level to obtain acceptable recovery. The sample results were flagged with a "–" to indicate that results were within contingency criteria (i.e., the V spike level was not 5 times greater than the concentration of V in the sample). Results were also flagged with an "SL" qualifier to indicate that an insufficient spike level had been used.

Precision of the MS/MSD analysis, expressed as the relative percent difference

(RPD) between the duplicate analyses, was within QC acceptance criteria of ±20% RPD for all metals except V, for which the RPD could not be calculated.

STANDARD REFERENCE MATERIAL ACCURACY:

Two SRMs were analyzed with the set of sediment samples: MESS-2, which is certified for all of the analytes of interest except BA, and PACS-2, which is certified for all metals of interest except Tl, for which consensus value is provided. SRM accuracy is expressed as the percent difference (PD) between the certified and measured concentrations of each metal of interest.

Accuracy of SRM MESS-2 recovery was within QC acceptance criteria of ± 20% (PD) for all metals except Ag (33%). Results for Ag were flagged with a "~" to indicate that results were within contingency criteria (i.e., the certified levels of Ag MESS-2 is not 10 times greater than its MDL). Accuracy of SRM PACS-2 recovery was within QC acceptance criteria for all metals except Be (37%) and Cr (30%). Results for Be were flagged with a "~" to indicate that results were within contingency criteria (i.e., the certified level is not 10 times greater than the MDL). Results reported for Cr analysis of PACS-2 by ICP-AES were confirmed by analysis by ICP-MS, and were flagged with an "&" to indicate that they exceeded QC acceptance criteria. No further corrective action was taken. Acceptable SRM recovery of Cr was demonstrated by analysis of MESS-2.

REPLICATE PRECISION:

Replicate precision was assessed by analysis of duplicate sample analysis. Precision of duplicate analyses, expressed as the RPD of replicate results was within the QC limits of ± 20% for all metals except Ag (36%) and As (34%). The sample results were flagged with a "~" to indicate that results were within contingency criteria (i.e., the concentrations of Ag and As in the samples were not 10 times greater than their respective MDLs).

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DEERFIELD RIVER - USACE NED
METALS IN SEDIMENT

(concentrations in µg/g dry wt - data are not blank corrected)

MSL Code	Sponsor ID		Ag	As	Ba	Be	Cd	Cr	Cu	Hg
		Run ID:	*I100901A*	*101501-6100A*	*I100901A*	*101501-6100A*	*101501-6100A*	*I100901A*	*I100901A*	*100901HGB2*
		Analysis:	*ICP-AES*	*ICP-MS*	*ICP-AES*	*ICP-MS*	*ICP-MS*	*ICP-AES*	*ICP-AES*	*CVAA*
1714-1 R1	AAK-0001-D		0.144	0.572	44.5	1.0 U	0.1 U	38.8	7.37	0.02 U
1714-1 R2	AAK-0001-D		0.100	0.802	45.7	1.0 U	0.1 U	33.0	7.80	0.02 U
1714-2	AAK-0002-D		0.179	0.974	45.9	1.0 U	0.109	49.2	6.82	0.02 U
1714-3	AAK-0003-D		0.143	0.782	37.9	1.0 U	0.154	45.7	5.70	0.239
1714-4	AAK-0004-D		0.1 U	1.13	50.2	2.24	0.1 U	39.9	7.75	0.02 U
1714-5	AAK-0005-D		0.104	1.27	64.3	1.0 U	0.1 U	39.9	8.15	0.02 U
1714-6	AAK-0006-D		0.127	1.46	24.5	1.0 U	0.187	52.8	5.70	0.02 U
1714-7	AAK-0007-D		0.1 U	0.774	60.0	1.0 U	0.1 U	35.9	6.25	0.02 U
1714-8	AAK-0008-D		0.1 U	0.928	74.2	1.0 U	0.123	36.9	12.2	0.02 U
1714-9	AAK-0009-D		0.149	0.508	33.5	1.0 U	0.145	56.8	7.94	0.02 U
1714-10	AAK-0002A		0.189	1.16	52.0	1.0 U	0.1 U	35.5	6.36	0.02 U
Target Detection Limits (Reporting Limits)			0.1	0.5	1.0	1.0	0.1	1.0	1.0	0.02
METHOD BLANK										
Blank			0.1 U	0.5 U	1.0 U	1.0 U	0.1 U	1.0 U	1.0 U	0.02 U
BLANK SPIKE ACCURACY										
Concentration Spiked			10	10	100	10	10	100	10	1.0
Blank			0.1 U	0.5 U	1.0 U	1.0 U	0.1 U	1.0 U	1.0 U	0.02 U
LCS R1			9.88	10.0	103	12.0	9.79	101	10.1	1.08
Concentration Recovered			9.88	10.0	103	12.0	9.79	101	10.1	1.08
Percent Recovery			**99%**	**100%**	**103%**	**120%**	**98%**	**101%**	**101%**	**108%**

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DEERFIELD RIVER - USACE NED
METALS IN SEDIMENT

(concentrations in µg/g dry wt - data are not blank corrected)

MSL Code	Sponsor ID		Ag	As	Ba	Be	Cd	Cr	Cu	Hg
		Run ID:	*I100901A*	*101501-6100A*	*I100901A*	*101501-6100A*	*101501-6100A*	*I100901A*	*I100901A*	*100901HGB2*
		Analysis:	*ICP-AES*	*ICP-MS*	*ICP-AES*	*ICP-MS*	*ICP-MS*	*ICP-AES*	*ICP-AES*	*CVAA*
MATRIX SPIKE ACCURACY										
Concentration Spiked			9.84	10	97.7	10	10	97.7	9.84	1.0
1714-4			0.1 U	1.13	50.2	2.24	0.1 U	39.9	7.75	0.02 U
1714-4 MS			9.43	10.5	150	12.1	9.54	129	15.6	1.09
Concentration Recovered			9.43	9.33	99.8	9.88	9.54	88.9	7.85	1.09
Percent Recovery			**96%**	**93%**	**102%**	**99%**	**95%**	**91%**	**80%**	**109%**
Concentration Spiked			10	10	96.5	10	10	96.5	10	1.0
1714-4			0.1 U	1.13	50.2	2.24	0.1 U	39.9	7.75	0.02 U
1714-4 MSD			9.41	11.4	143	12.4	12.4	133	16.3	1.11
Concentration Recovered			9.31	10.2	93.2	10.1	12.4	93.0	8.55	1.11
Percent Recovery			**93%**	**102%**	**97%**	**101%**	**124%**	**96%**	**85%**	**111%**
	RPD		**3%**	**9%**	**6%**	**2%**	**26%**	**6%**	**7%**	**2%**
SRM ACCURACY										
MESS-2			0.120	18.5	797	2.29	0.234	88.8	33.8	0.0935
	Certified Value		0.18	20.7	NC	2.32	0.24	106	39.3	0.092
	Range		±0.12	±0.8		±0.12	±0.01	±8.0	±2.0	±0.009
	percent difference		**33% ~**	**11%**	**NA**	**1%**	**2%**	**16%**	**14%**	**2%**
PACS-2			1.09	23.7	661	0.626	2.02	63.3	289	3.25
	Certified Value		1.22	26.2	NC	1.0	2.11	90.7	310	3.04
	Range		±0.14	±1.5		±0.2	±0.15	±4.6	±12	±0.20
	percent difference		**11%**	**9%**	**NA**	**37% ~**	**4%**	**30% &**	**7%**	**7%**

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DEERFIELD RIVER - USACE NED
METALS IN SEDIMENT

(concentrations in µg/g dry wt - data are not blank corrected)

MSL Code	Sponsor ID		Ag	As	Ba	Be	Cd	Cr	Cu	Hg
		Run ID:	*I100901A*	*101501-6100A*	*I100901A*	*101501-6100A*	*101501-6100A*	*I100901A*	*I100901A*	*100901HGB2*
		Analysis:	*ICP-AES*	*ICP-MS*	*ICP-AES*	*ICP-MS*	*ICP-MS*	*ICP-AES*	*ICP-AES*	*CVAA*
REPLICATE PRECISION										
1714-1 R1			0.144	0.572	44.5	1.0 U	0.1 U	38.8	7.37	0.02 U
1714-1 R2			0.100	0.802	45.7	1.0 U	0.1 U	33.0	7.80	0.02 U
	RPD		36% ~	34% ~	3%	0%	0%	16%	6%	0%
	Mean		0.122	0.687	45.1	1.0 U	0.1 U	35.9	7.59	0.02 U

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DEERFIELD RIVER - USACE NED
METALS IN SEDIMENT

(concentrations in µg/g dry wt - data are not blank corrected)

MSL Code	Sponsor ID		Ni	Pb	Sb	Se	Tl	V	Zn
		Run ID:	*I100901A*	*101501-6100A*	*101501-6100A*	*F101201A-Se*	*101501-6100A*	*I100901A*	*I100901A*
		Analysis:	*ICP-AES*	*ICP-MS*	*ICP-MS*	*FIAS*	*ICP-MS*	*ICP-AES*	*ICP-AES*
1714-1 R1	AAK-0001-D		16.1	7.10	1.0 U	0.1 U	0.112	48.6	39.5
1714-1 R2	AAK-0001-D		16.4	7.93	1.0 U	0.1 U	0.108	44.0	38.7
1714-2	AAK-0002-D		15.0	5.94	1.0 U	0.1 U	0.1 U	48.7	38.5
1714-3	AAK-0003-D		10.9	5.90	1.0 U	0.1 U	0.1 U	53.4	39.4
1714-4	AAK-0004-D		17.2	6.81	1.0 U	0.1 U	0.117	54.4	42.3
1714-5	AAK-0005-D		18.7	7.82	1.0 U	0.1 U	0.196	48.1	38.5
1714-6	AAK-0006-D		12.0	3.37	1.0 U	0.1 U	0.1 U	67.1	38.0
1714-7	AAK-0007-D		15.3	8.01	1.0 U	0.1 U	0.170	40.4	35.5
1714-8	AAK-0008-D		19.8	10.6	1.0 U	0.1 U	0.194	48.8	49.6
1714-9	AAK-0009-D		13.7	4.19	1.0 U	0.1 U	0.115	67.3	42.8
1714-10	AAK-0002A		16.0	6.55	1.0 U	0.1 U	0.113	42.4	41.0
Target Detection Limits (Reporting Limits)			1.0	1.0	1.0	0.1	0.1	1.0	1.0
METHOD BLANK									
Blank			1.0 U	1.0 U	1.0 U	0.1 U	0.1 U	1.0 U	1.0 U
BLANK SPIKE ACCURACY									
Concentration Spiked			100	100	10	10	10	10	100
Blank			1.0 U	1.0 U	1.0 U	0.1 U	0.1 U	1.0 U	1.0 U
LCS R1			101	103.9	9.72	10.4	10.1	9.87	100
Concentration Recovered			101	104	9.72	10.4	10.1	9.87	100
Percent Recovery			**101%**	**104%**	**97%**	**104%**	**101%**	**99%**	**100%**

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DEERFIELD RIVER - USACE NED
METALS IN SEDIMENT

(concentrations in µg/g dry wt - data are not blank corrected)

MSL Code	Sponsor ID		Ni	Pb	Sb	Se	Tl	V	Zn
		Run ID:	*I100901A*	*101501-6100A*	*101501-6100A*	*F101201A-Se*	*101501-6100A*	*I100901A*	*I100901A*
		Analysis:	*ICP-AES*	*ICP-MS*	*ICP-MS*	*FIAS*	*ICP-MS*	*ICP-AES*	*ICP-AES*
MATRIX SPIKE ACCURACY									
Concentration Spiked			97.7	100	10	10	10	9.84	97.7
1714-4			17.2	6.81	1.0 U	1.0 U	0.117	54.4	42.3
1714-4 MS			107	105	9.66	10.2	9.79	53.4	132
Concentration Recovered			90.2	98.6	9.66	10.2	9.67	1.0 U	89.3
Percent Recovery			**92%**	**99%**	**97%**	**102%**	**97%**	**NA -SL**	**91%**
Concentration Spiked			96.5	100	10	10	10	10	96.5
1714-4			17.2	6.81	1.0 U	1.0 U	0.113	54.4	42.3
1714-4 MSD			107	105	10.1	10.4	10.3	58.2	133
Concentration Recovered			89.5	97.9	10.1	10.4	10.2	3.80	91.1
Percent Recovery			**93%**	**98%**	**101%**	**104%**	**102%**	**38% -SL**	**94%**
	RPD		**0%**	**1%**	**5%**	**2%**	**5%**	**NA**	**3%**
SRM ACCURACY									
MESS-2			46.9	20.5	0.888 J	0.774	0.871	217	150
	Certified Value		49.3	21.9	1.09	0.72	0.98	252	172
	Range		±1.8	±1.2	±0.13	±0.09	--	±10	±16
	percent difference		**5%**	**7%**	**19%**	**8%**	**11%**	**14%**	**13%**
PACS-2			34.8	165	9.54	0.743	0.526	111	338
	Certified Value		39.5	183	11.3	0.92	0.6	133	364
	Range		±2.3	±12	±2.6	±0.22	--	±5	±23
	percent difference		**12%**	**10%**	**16%**	**19%**	**12%**	**16%**	**7%**

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DEERFIELD RIVER - USACE NED
METALS IN SEDIMENT

MSL Code	Sponsor ID		Ni	Pb	Sb	Se	Tl	V	Zn
			(concentrations in µg/g dry wt - data are not blank corrected)						
		Run ID:	*I100901A*	*101501-6100A*	*101501-6100A*	*F101201A-Se*	*101501-6100A*	*I100901A*	*I100901A*
		Analysis:	*ICP-AES*	*ICP-MS*	*ICP-MS*	*FIAS*	*ICP-MS*	*ICP-AES*	*ICP-AES*
REPLICATE PRECISION									
1714-1 R1			16.1	7.10	1.0 U	0.1 U	0.112	48.6	39.5
1714-1 R2			16.4	7.93	1.0 U	0.1 U	0.108	44.0	38.7
	RPD		2%	11%	0%	0%	4%	10%	2%
	Mean		16.2	7.51	1.0 U	0.1 U	0.110	46.3	39.1

U Not detected; Target Detection Limit reported
J Analyte detected at level <lab MDL.
NA Not applicable/available
NC Not certified
SL Inappropriate spike level
& QC value outside the accuracy or precision criteria goal (SRM ±20% PD; Spike Recovery ±30%; Replicate Precision <30% RPD).
~ QC value outside the accuracy or precision data quality objective, but meets contingency criteria (Blank: samples >10X blank concentration; MS: analyte >5X background concentration (SRM and Replicates: analyte >10X MDL).

Attachment 5

PCB Results

PCB Congener – SEDIMENT QA/QC SUMMARY

PROJECT	Deerfield River
PARAMETER	PCB
LABORATORY	Arthur D. Little, Inc
BATCH IDS	B1905, B1957
MATRIX	Sediment
SAMPLE CUSTODY	Nine sediment samples were received from Battelle Memorial Institute (Duxbury) on September 28, 2001. All sample containers were intact and the sediment samples frozen. No deviations from normal protocols were noted. Analytical requirements were for selected PCB congeners by GC-ECD and selected PAHs by GC/MS. One extra sample was collected on 10/22/01 and analyzed on 11/21/01 for selected PCB congeners.

QA/QC DATA QUALITY OBJECTIVES:

	Reference Method	Surrogate Recovery	LCS/MS Recovery	SRM % Diff.	MS/MSD & Sample Replicate Relative Precision	Achieved Detection Limit (μg/kg DW)	Target Detection Limit (μg/kg DW)
PCB	General NS&T	40-120% Recovery	40-120% Recovery (for at least 80% of analytes; analyte conc. in MS must be >5x background)	≤30% PD (from range of certified values, for analytes >10x MDL)	≤30% RPD (analyte conc. in MS must be >5x background)	PCB ~0.089 – 0.24	PCB 1.0

EXTRACTION METHOD: Sediment samples were extracted for PCBs following general NS&T methodologies. Approximately 50-g of well mixed, wet sediment was extracted three times with dichloromethane using sonication techniques. The third sonication extract was additionally extracted on a shaker table for 1-hour before decanting and combining it with the first two extracts. The combined extract was dried over anhydrous sodium sulfate, concentrated, cleaned with activated copper, and eluted through F-20 alumina column. The extract was concentrated further and submitted for HPLC cleanup with a pre-HPLC archive taken. The post-HPLC extract was concentrated, split quantitatively for GC/ECD and GC/MS analyses. The GC/ECD extracts were solvent exchanged into hexane, additionally acid cleaned, fortified with Recovery standards and the pre injection volume adjusted to 250uL. Samples were submitted and analyzed following general NS&T methods using a gas chromatograph equipped with dual columns and dual electron capture detectors (GC/ECD). Sample data were quantified by the method of internal standards, using the Recovery Internal Standard (RIS) compounds.

HOLDING TIMES: Sediment samples for PAH and PCB analyses were received and stored frozen until extraction. The client gave no dates of field collection.

Batch	Extraction Date	Analysis Date
B1905	10/05/01	10/12/01 - 10/13/01
B1957	11/05/01	11/21/01

PCB Congener – SEDIMENT QA/QC SUMMARY

DETECTION LIMITS:

Achieved detection limits were less than the required Target Detection Limits provided by Battelle. Achieved detection limits for pesticides and PCBs are based on a 7 replicate MDL study and adjusted for the average dry weight of the batch.

Otherwise, censored PCB results for authentic samples and the PB are reported using Target Detection Limits (PCB 1.0 μg/kg, dry), noted as Client Reporting Limits.

BLANKS:

A procedural blank (PB) was prepared with the analytical batch. The blank was analyzed to ensure the sample extraction and analysis methods were free of contamination.

Batch B1905– PCBs were undetected in the procedural blank at levels above the target MRL.

Batch B1957- PCBs were undetected in the procedural blank at levels above the target MRL.

LABORATORY CONTROL SAMPLES (Blank Spike and Blank Spike Duplicate)

A laboratory control samples (LCS, Blank Spike, Blank Spike Duplicate) were prepared with the sediment analytical batch (B1905 and B1957). The percent recoveries of PCB congeners were calculated to measure data quality in terms of accuracy. The relative percent difference (RPD) between percent recoveries of PCBs in the BS and BSD were calculated to measure data quality in terms of precision.

Batch B1905 – PCBs were recovered within the laboratory control limits specified by the method (40 – 120%) and ranged from 60 – 99% recoveries in the BS and 60-105% recoveries in the BSD. The RPDs of the BS/BSD ranged from 0 – 9.5%.

Batch B1957 - PCBs were recovered within the laboratory control limits specified by the method (40 – 120%) and ranged from 50 – 77% recoveries in the BS and 46-68% recoveries in the BSD. The RPDs of the BS/BSD ranged from 3.3 – 120%. Several RPDs were out of the acceptable range but the MS/MSDs, IRM and SRM that were analyzed with this batch of samples were acceptable, therefore, no corrective action was necessary.

PCB Congener – SEDIMENT QA/QC SUMMARY

MATRIX SPIKES:

A matrix spike (MS)/matrix spike duplicate (MSD) sample was prepared with the analytical batch. The percent recoveries of PCBs in the MS/MSD were calculated to measure data quality in terms of accuracy. The relative percent difference (RPD) between percent recoveries of PCBs in the MS and MSD were calculated to measure data quality in terms of precision.

Batch B1905 – Percent recoveries and RPDs were within the laboratory control limits specified by the method (40 – 120% recovery and RPD<30%, where concentration in MS >5x background). Percent recoveries ranged from 66-115% for the MS and 64%-108% for the MSD. The RPDs ranged from 3.1-7.8%, indicating excellent precision.

Batch B1957 – No MS/MSD data is reported with this sample.

SURROGATES:

Three surrogate compounds were added prior to extraction, including Dibromo-octafluoro-biphenyl (DBOFB), PCB103, and PCB198. The recovery of each surrogate compound was calculated to measure data quality in terms of accuracy (extraction efficiency).

Batch B1905– Surrogates were recovered within the control limits (40–120%) for all samples with the exception of two samples:

21A2590MS	125% PCB103
DO-S-56SRM	129% PCB198

Corrective Action 21A2590MS – Since all other surrogate and spiked analyte recoveries associated with 21A2590MS, 21A2590MSD, 21A2590 were within control limits, and the data was not surrogate corrected, no corrective action was necessary.

Corrective Action DO-S-56SRM – Since all other surrogates were within control limits, and the data was not surrogate corrected, no corrective action was necessary.

Batch B1957– Surrogates were recovered within the control limits (40–120%) for all samples.

REPLICATES:

A sample duplicate was prepared with the analytical batch. The RPD between replicate analyses for PCBs was calculated to measure data quality in terms of precision.

Batch B1905– RPDs were within the control limits for all Pest/PCBs (≤30%, for analytes >10x MDL) and were all 0% RPD.

Batch B1957– No duplicate sample results are reported with this sample.

PCB Congener – SEDIMENT QA/QC SUMMARY

SRM:

A standard reference material (SRM, NIST 1944) was prepared with the analytical batch. The percent difference (PD) between the measured value and the certified range was calculated to measure data quality in terms of accuracy. ***Note*** – if the detected value fell within the certified range, then the PD is 0.0%.

Batch B1905 – SRM PDs were within the control limits ($\leq$30% from certified range, for analytes >5x MDL) for all certified PCBs except PCB187, with a PD of 117%. All remaining PDs ranged from 1.0 – 29.1%.

Corrective Action – Since recovery of PCB187 in IRM sample was within control limits, and there were no reported PCB187 values in any of the samples, no additional corrective action was necessary.

Batch B1957 – SRM PDs were within the control limits ($\leq$30% from certified range, for analytes >5x MDL) for all certified PCBs except PCB66 (PD of 31.3%), PCB170 (PD of 34.5%), PCB87 (PD of 271%), PCB187 (PD of 154%), and PCB195 (PD of 33.9%). All remaining PDs ranged from 1.33 - 28.6%.

Corrective Action – Recoveries of these congeners in the BS/BSD and IRM were acceptable. No corrective action was taken.

IRM:

An instrument reference standard (made from SRM, NIST 1493) is analyzed to check instrument performance with each analytical sequence. The percent difference (PD) between the measured value and the certified range was calculated to measure data quality in terms of accuracy.

Batch B1905 – IRM PDs were within the control limits ($\leq$30% from certified range, for analytes >5x MDL) for all certified PCBs. PDs ranged from 9.55-14.5%.

Batch B1957 – IRM PDs were within the control limits ($\leq$30% from certified range, for analytes >5x MDL) for all certified PCBs. PDs ranged from 0.502 - 12.7%.

Miscellaneous documentation:

Per client request, a 1.0 ug/Kg-reporting limit was used instead of the calculated Minimum Reporting Limit (MRL). The calculated MRL is displayed in the spreadsheet header to demonstrate the Target reporting Limit (TRL) achieved.

Arthur D. Little
Environmental Chemistry and Forensics Unit

Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3671
Data Table: Main - Not Surrogate Corrected

Field ID	AAK-001-C	AAK-002-C	AAK-003-C
Lab ID	21A2583	21A2584	21A2585
Lab Batch	B1905	B1905	B1905
SDG	ADL3671	ADL3671	ADL3671
File	10110108.D	10110109.D	10110110.D
Sample Type	N	N	N
Matrix	SEDIMENT	SEDIMENT	SEDIMENT
Sample Size	40.32 g	43.35 g	44.16 g
Weight Basis	DRY	DRY	DRY
Associated Blank	DO-S-53PB	DO-S-53PB	DO-S-53PB
Field Date	09/05/01	09/06/01	09/06/01
Extract Date	10/05/01	10/05/01	10/05/01
Analysis Date	10/12/01	10/12/01	10/12/01
Date Received	09/28/01	09/28/01	09/28/01
Percent Solids	80.5	86.5	87.8
Dilution Factor	1	1	1
Percent Lipids	NA	NA	NA
Report Method	8082 - PCB Congener - GC-ECD	8082 - PCB Congener - GC-ECD	8082 - PCB Congener - GC-ECD
Client Reporting Limit	1	1	1
Min Reporting Limit	0.082	0.068	0.049
Units	ug/Kg	ug/Kg	ug/Kg

PCB Congener - GCECD			
8 - 2,4'-Dichlorobiphenyl	1 U	1 U	1 U
18 - 2,2',5-Trichlorobiphenyl	1 U	1 U	1 U
28 - 2,4,4'-Trichlorobiphenyl	1 U	1 U	1 U
44 - 2,2',3,5'-Tetrachlorobiphenyl	1 U	1 U	1 U
49 - 2,2',4,5'-Tetrachlorobiphenyl	1 U	1 U	1 U
52 - 2,2',5,5'-Tetrachlorobiphenyl	1 U	1 U	1 U
66 - 2,3',4,4'-Tetrachlorobiphenyl	1 U	1 U	1 U
87 - 2,2',3,4,5'-Pentachlorobiphenyl	1 U	1 U	1 U
101 - 2,2',4,5,5'-Pentachlorobiphenyl	1 U	1 U	1 U
105 - 2,3,3',4,4'-Pentachlorobiphenyl	1 U	1 U	1 U
118 - 2,3',4,4',5-Pentachlorobiphenyl	1 U	1 U	1 U
128 - 2,2',3,3',4,4'-Hexachlorobiphenyl	1 U	1 U	1 U
138 - 2,2',3,4,4',5'-Hexachlorobiphenyl	1 U	1 U	1 U
153 - 2,2',4,4',5,5'-Hexachlorobiphenyl	1 U	1 U	1 U
170 - 2,2',3,3',4,4',5-Heptachlorobiphenyl	1 U	1 U	1 U
180 - 2,2',3,4,4',5,5'-Heptachlorobiphenyl	1 U	1 U	1 U
183 - 2,2',3,4,4',5',6-Heptachlorobiphenyl	1 U	1 U	1 U
184 - 2,2',3,4,4',6,6'-Heptachlorobiphenyl	1 U	1 U	1 U
187 - 2,2',3,4',5,5',6-Heptachlorobiphenyl	1 U	1 U	1 U
195 - 2,2',3,3',4,4',5,6-Octachlorobiphenyl	1 U	1 U	1 U
206 - 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl	1 U	1 U	1 U
209 - Decachlorobiphenyl	1 U	1 U	1 U
Total PCB	ND	ND	ND
Dibromo-octafluoro-biphenyl	84	80	73
103 - 2,2',4,5',6-Pentachlorobiphenyl	91	98	84
198 - 2,2',3,3',4,5,5',6-Octachlorobiphenyl	109	108	94

Arthur D. Little
Environmental Chemistry and Forensics Unit

Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3671
Data Table: Main - Not Surrogate Corrected

Field ID	AAK-004-C	AAK-005-C	AAK-006-C
Lab ID	21A2586	21A2587	21A2588
Lab Batch	B1905	B1905	B1905
SDG	ADL3671	ADL3671	ADL3671
File	10110111.D	10110116.D	10110112.D
Sample Type	N	N	N
Matrix	SEDIMENT	SEDIMENT	SEDIMENT
Sample Size	41.74 g	41.02 g	26.45 g
Weight Basis	DRY	DRY	DRY
Associated Blank	DO-S-53PB	DO-S-53PB	DO-S-53PB
Field Date	09/05/01	09/05/01	09/05/01
Extract Date	10/05/01	10/05/01	10/05/01
Analysis Date	10/12/01	10/12/01	10/12/01
Date Received	09/28/01	09/28/01	09/28/01
Percent Solids	83.3	81.4	88.1
Dilution Factor	1	1	1
Percent Lipids	NA	NA	NA
Report Method	8082 - PCB Congener - GC-ECD	8082 - PCB Congener - GC-ECD	8082 - PCB Congener - GC-ECD
Client Reporting Limit	1	1	1
Min Reporting Limit	0.06	0.061	0.088
Units	ug/Kg	ug/Kg	ug/Kg

PCB Congener - GCECD			
8 - 2,4'-Dichlorobiphenyl	1 U	1 U	1 U
18 - 2,2',5-Trichlorobiphenyl	1 U	1 U	1 U
28 - 2,4,4'-Trichlorobiphenyl	1 U	1 U	1 U
44 - 2,2',3,5'-Tetrachlorobiphenyl	1 U	1 U	1 U
49 - 2,2',4,5'-Tetrachlorobiphenyl	1 U	1 U	1 U
52 - 2,2',5,5'-Tetrachlorobiphenyl	1 U	1 U	1 U
66 - 2,3',4,4'-Tetrachlorobiphenyl	1 U	1 U	1 U
87 - 2,2',3,4,5'-Pentachlorobiphenyl	1 U	1 U	1 U
101 - 2,2',4,5,5'-Pentachlorobiphenyl	1 U	1 U	1 U
105 - 2,3,3',4,4'-Pentachlorobiphenyl	1 U	1 U	1 U
118 - 2,3',4,4',5-Pentachlorobiphenyl	1 U	1 U	1 U
128 - 2,2',3,3',4,4'-Hexachlorobiphenyl	1 U	1 U	1 U
138 - 2,2',3,4,4',5'-Hexachlorobiphenyl	1 U	1 U	1 U
153 - 2,2',4,4',5,5'-Hexachlorobiphenyl	1 U	1 U	1 U
170 - 2,2',3,3',4,4',5-Heptachlorobiphenyl	1 U	1 U	1 U
180 - 2,2',3,4,4',5,5'-Heptachlorobiphenyl	1 U	1 U	1 U
183 - 2,2',3,4,4',5',6-Heptachlorobiphenyl	1 U	1 U	1 U
184 - 2,2',3,4,4',6,6'-Heptachlorobiphenyl	1 U	1 U	1 U
187 - 2,2',3,4',5,5',6-Heptachlorobiphenyl	1 U	1 U	1 U
195 - 2,2',3,3',4,4',5,6-Octachlorobiphenyl	1 U	1 U	1 U
206 - 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl	1 U	1 U	1 U
209 - Decachlorobiphenyl	1 U	1 U	1 U
Total PCB	ND	ND	ND
Dibromo-octafluoro-biphenyl	72	79	66
103 - 2,2',4,5',6-Pentachlorobiphenyl	76	109	78
198 - 2,2',3,3',4,5,5',6-Octachlorobiphenyl	92	104	85

Arthur D. Little
Environmental Chemistry and Forensics Unit

Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3671
Data Table: Main - Not Surrogate Corrected

Field ID	AAK-007-C	AAK-008-C	AAK-009-C
Lab ID	21A2589	21A2590	21A2591
Lab Batch	B1905	B1905	B1905
SDG	ADL3671	ADL3671	ADL3671
File	10110117.D	10110118.D	10110121.D
Sample Type	N	N	N
Matrix	SEDIMENT	SEDIMENT	SEDIMENT
Sample Size	44.53 g	24.6 g	43.07 g
Weight Basis	DRY	DRY	DRY
Associated Blank	DO-S-53PB	DO-S-53PB	DO-S-53PB
Field Date	09/05/01	09/05/01	09/06/01
Extract Date	10/05/01	10/05/01	10/05/01
Analysis Date	10/12/01	10/12/01	10/13/01
Date Received	09/28/01	09/28/01	09/28/01
Percent Solids	88.4	81.4	85.7
Dilution Factor	1	1	1
Percent Lipids	NA	NA	NA
Report Method	8082 - PCB Congener - GC-ECD	8082 - PCB Congener - GC-ECD	8082 - PCB Congener - GC-ECD
Client Reporting Limit	1	1	1
Min Reporting Limit	0.045	0.081	0.055
Units	ug/Kg	ug/Kg	ug/Kg

PCB Congener - GCECD			
8 - 2,4'-Dichlorobiphenyl	1 U	1 U	1 U
18 - 2,2',5-Trichlorobiphenyl	1 U	1 U	1 U
28 - 2,4,4'-Trichlorobiphenyl	1 U	1 U	1 U
44 - 2,2',3,5'-Tetrachlorobiphenyl	1 U	1 U	1 U
49 - 2,2',4,5'-Tetrachlorobiphenyl	1 U	1 U	1 U
52 - 2,2',5,5'-Tetrachlorobiphenyl	1 U	1 U	1 U
66 - 2,3',4,4'-Tetrachlorobiphenyl	1 U	1 U	1 U
87 - 2,2',3,4,5'-Pentachlorobiphenyl	1 U	1 U	1 U
101 - 2,2',4,5,5'-Pentachlorobiphenyl	1 U	1 U	1 U
105 - 2,3,3',4,4'-Pentachlorobiphenyl	1 U	1 U	1 U
118 - 2,3',4,4',5-Pentachlorobiphenyl	1 U	1 U	1 U
128 - 2,2',3,3',4,4'-Hexachlorobiphenyl	1 U	1 U	1 U
138 - 2,2',3,4,4',5'-Hexachlorobiphenyl	1 U	1 U	1 U
153 - 2,2',4,4',5,5'-Hexachlorobiphenyl	1 U	1 U	1 U
170 - 2,2',3,3',4,4',5-Heptachlorobiphenyl	1 U	1 U	1 U
180 - 2,2',3,4,4',5,5'-Heptachlorobiphenyl	1 U	1 U	1 U
183 - 2,2',3,4,4',5',6-Heptachlorobiphenyl	1 U	1 U	1 U
184 - 2,2',3,4,4',6,6'-Heptachlorobiphenyl	1 U	1 U	1 U
187 - 2,2',3,4',5,5',6-Heptachlorobiphenyl	1 U	1 U	1 U
195 - 2,2',3,3',4,4',5,6-Octachlorobiphenyl	1 U	1 U	1 U
206 - 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl	1 U	1 U	1 U
209 - Decachlorobiphenyl	1 U	1 U	1 U
Total PCB	ND	ND	ND
Dibromo-octafluoro-biphenyl	80	79	70
103 - 2,2',4,5',6-Pentachlorobiphenyl	77	109	89
198 - 2,2',3,3',4,5,5',6-Octachlorobiphenyl	97	102	100

Arthur D. Little
Environmental Chemistry and Forensics Unit

Project Title : Battelle - CT River & Bridgeport, CT
Data Package: 3744
Data Table: Main Censored - Not Surrogate Corrected

Field ID	Sample 2A - R
Lab ID	W8250
ADL ID	21A3064
SDG	ADL3744
File	11160163.D
Sample Type	N
Matrix	SEDIMENT
Sample Size	24.07 g
Weight Basis	DRY
% Moisture (%)	79.3
Associated Blank	DP-S-81PB
Field Date	10/22/01
Extract Date	11/05/01
Analysis Date	11/21/01
Date Received	10/25/01
Percent Solids	79.2
Dilution Factor	1
Percent Lipids	NA
Report Method	8081M PCB Congener
Min Reporting Limit	0.18
Units	ug/Kg

PCB Congener		
8 - 2,4'-Dichlorobiphenyl (Cl2)	1	U
18 - 2,2',5-Trichlorobiphenyl (Cl3)	1	U
28 - 2,4,4'-Trichlorobiphenyl (Cl3)	1	U
44 - 2,2',3,5'-Tetrachlorobiphenyl (Cl4)	1	U
49 - 2,2',4,5'-Tetrachlorobiphenyl (Cl4)	1	U
52 - 2,2',5,5'-Tetrachlorobiphenyl (Cl4)	1	U
66 - 2,3',4,4'-Tetrachlorobiphenyl (Cl4)	1	U
87 - 2,2'3,4,5'-Pentachlorobiphenyl (Cl5)	1	U
101 - 2,2',4,5,5'-Pentachlorobiphenyl (Cl5)	1	U
105 - 2,3,3',4,4'-Pentachlorobiphenyl (Cl5)	1	U
118 - 2,3',4,4',5-Pentachlorobiphenyl (Cl5)	1	U
128 - 2,2',3,3',4,4'-Hexachlorobiphenyl (Cl6)	1	U
138 - 2,2',3,4,4',5'-Hexachlorobiphenyl (Cl6)	1	U
153 - 2,2',4,4',5,5'-Hexachlorobiphenyl (Cl6)	1	U
170 - 2,2',3,3',4,4',5-Heptachlorobiphenyl (Cl7)	1	U
180 - 2,2',3,4,4',5,5'-Heptachlorobiphenyl (Cl7)	1	U
183 - 2,2',3,4,4',5',6-Heptachlorobiphenyl (Cl7)	1	U
184 - 2,2',3,4,4',6,6'-Heptachlorobiphenyl (Cl7)	1	U
187 - 2,2',3,4',5,5',6-Heptachlorobiphenyl (Cl7)	1	U
195 - 2,2',3,3',4,4',5,6-Octachlorobiphenyl (Cl8)	1	U
206 - 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl (Cl9)	1	U
209 - 2,2',3,3',4,4',5,5',6,6'-Decachlorobiphenyl (Cl10)	1	U
Total PCB Congeners	ND	
Dibromo-octafluoro-biphenyl	60	
103 - 2,2',4,5',6-Pentachlorobiphenyl	84	
198 - 2,2',3,3',4,5,5',6-Octachlorobiphenyl	81	

Arthur D. Little
Environmental Chemistry and Forensics Unit

Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3671
Data Table: BS-BSD - Not Surrogate Corrected

Field ID	Procedural Blank	Blank Spike			
Lab ID	DO-S-53PB	DO-S-54BS			
Lab Batch	B1905	B1905			
SDG	ADL3671	ADL3671			
File	10110104.D	10110105.D			
Sample Type	PB	BS			
Matrix	SEDIMENT	SEDIMENT			
Sample Size	30 g	30 g			
Weight Basis	DRY	DRY			
Associated Blank	NA	DO-S-53PB			
Field Date	10/05/01	10/05/01			
Extract Date	10/05/01	10/05/01			
Analysis Date	10/11/01	10/11/01			
Date Received	10/05/01	10/05/01			
Percent Solids	100	100			
Dilution Factor	1	1			
Percent Lipids	NA	NA			
Report Method	8082 - PCB Congener - GC-ECD	8082 - PCB Congener - GC-ECD			
Client Reporting Limit	1	1			
Min Reporting Limit	0.074	0.067			
Units	ug/Kg	ug/Kg	T	%R	Q
PCB Congener - GCECD					
8 - 2,4'-Dichlorobiphenyl	1 U	2	3.33	60	
18 - 2,2',5-Trichlorobiphenyl	1 U	1 U			
28 - 2,4,4'-Trichlorobiphenyl	1 U	2.8	3.33	84	
44 - 2,2',3,5'-Tetrachlorobiphenyl	1 U	1 U			
49 - 2,2',4,5'-Tetrachlorobiphenyl	1 U	1 U			
52 - 2,2',5,5'-Tetrachlorobiphenyl	1 U	2.4	3.33	72	
66 - 2,3',4,4'-Tetrachlorobiphenyl	1 U	1 U			
87 - 2,2',3,4,5'-Pentachlorobiphenyl	1 U	1 U			
101 - 2,2',4,5,5'-Pentachlorobiphenyl	1 U	2.8	3.33	84	
105 - 2,3,3',4,4'-Pentachlorobiphenyl	1 U	1 U			
118 - 2,3',4,4',5-Pentachlorobiphenyl	1 U	1 U			
128 - 2,2',3,3',4,4'-Hexachlorobiphenyl	1 U	3.1	3.33	93	
138 - 2,2',3,4,4',5'-Hexachlorobiphenyl	1 U	1 U			
153 - 2,2',4,4',5,5'-Hexachlorobiphenyl	1 U	2.9	3.33	87	
170 - 2,2',3,3',4,4',5-Heptachlorobiphenyl	1 U	1 U			
180 - 2,2',3,4,4',5,5'-Heptachlorobiphenyl	1 U	3	3.33	90	
183 - 2,2',3,4,4',5',6-Heptachlorobiphenyl	1 U	1 U			
184 - 2,2',3,4,4',6,6'-Heptachlorobiphenyl	1 U	1 U			
187 - 2,2',3,4',5,5',6-Heptachlorobiphenyl	1 U	1 U			
195 - 2,2',3,3',4,4',5,6-Octachlorobiphenyl	1 U	1 U			
206 - 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl	1 U	3.3	3.33	99	
209 - Decachlorobiphenyl	1 U	3.1	3.33	93	
Total PCB	ND	51			
Dibromo-octafluoro-biphenyl	79	79			
103 - 2,2',4,5',6-Pentachlorobiphenyl	80	73			
198 - 2,2',3,3',4,5,5',6-Octachlorobiphenyl	96	92			

Arthur D. Little
Environmental Chemistry and Forensics Unit

Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3671
Data Table: BS-BSD - Not Surrogate Corrected

Field ID	Blank Spike Duplicate					
Lab ID	DO-S-55BSD					
Lab Batch	B1905					
SDG	ADL3671					
File	10110106.D					
Sample Type	BSD					
Matrix	SEDIMENT					
Sample Size	30 g					
Weight Basis	DRY					
Associated Blank	DO-S-53PB					
Field Date	10/05/01					
Extract Date	10/05/01					
Analysis Date	10/11/01					
Date Received	10/05/01					
Percent Solids	100					
Dilution Factor	1					
Percent Lipids	NA					
Report Method	8082 - PCB Congener - GC-ECD					
Client Reporting Limit	1					
Min Reporting Limit	0.067					
Units	ug/Kg		T	%R	Q RPD	Q
PCB Congener - GCECD						
8 - 2,4'-Dichlorobiphenyl	2		3.33	60	0	
18 - 2,2',5-Trichlorobiphenyl	1	U				
28 - 2,4,4'-Trichlorobiphenyl	2.9		3.33	87	3.5	
44 - 2,2',3,5'-Tetrachlorobiphenyl	1	U				
49 - 2,2',4,5'-Tetrachlorobiphenyl	1	U				
52 - 2,2',5,5'-Tetrachlorobiphenyl	2.5		3.33	75	4.1	
66 - 2,3',4,4'-Tetrachlorobiphenyl	1	U				
87 - 2,2',3,4,5'-Pentachlorobiphenyl	1	U				
101 - 2,2',4,5,5'-Pentachlorobiphenyl	3		3.33	90	6.9	
105 - 2,3,3',4,4'-Pentachlorobiphenyl	1	U				
118 - 2,3',4,4',5-Pentachlorobiphenyl	1	U				
128 - 2,2',3,3',4,4'-Hexachlorobiphenyl	3.3		3.33	99	6.2	
138 - 2,2',3,4,4',5'-Hexachlorobiphenyl	1	U				
153 - 2,2',4,4',5,5'-Hexachlorobiphenyl	3.1		3.33	93	6.7	
170 - 2,2',3,3',4,4',5-Heptachlorobiphenyl	1	U				
180 - 2,2',3,4,4',5,5'-Heptachlorobiphenyl	3.3		3.33	99	9.5	
183 - 2,2',3,4,4',5',6-Heptachlorobiphenyl	1	U				
184 - 2,2',3,4,4',6,6'-Heptachlorobiphenyl	1	U				
187 - 2,2',3,4',5,5',6-Heptachlorobiphenyl	1	U				
195 - 2,2',3,3',4,4',5,6-Octachlorobiphenyl	1	U				
206 - 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl	3.5		3.33	105	5.9	
209 - Decachlorobiphenyl	3.3		3.33	99	6.2	
Total PCB	54					
Dibromo-octafluoro-biphenyl	78					
103 - 2,2',4,5',6-Pentachlorobiphenyl	76					
198 - 2,2',3,3',4,5,5',6-Octachlorobiphenyl	97					

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Environmental Chemistry and Forensics Unit

Project Title : Battelle - CT River & Bridgeport, CT
Data Package: 3744
Data Table: BS-BSD - Not Surrogate Corrected

Field ID	Procedural Blank	Blank Spike			
Lab ID	DP-S-81PB	DP-S-82BS			
Lab Batch	B1957	B1957			
SDG	ADL3744	ADL3744			
File	11160138.D	11160139.D			
Sample Type	PB	BS			
Matrix	SEDIMENT	SEDIMENT			
Sample Size	20 g	20 g			
Weight Basis	DRY	DRY			
% Moisture (%)	NA	NA			
Associated Blank	NA	DP-S-81PB			
Field Date	11/05/01	11/05/01			
Extract Date	11/05/01	11/05/01			
Analysis Date	11/19/01	11/19/01			
Date Received	11/05/01	11/05/01			
Percent Solids	100	100			
Dilution Factor	1	1			
Percent Lipids	NA	NA			
Report Method	8081M PCB Congener	8081M PCB Congener			
Min Reporting Limit	0.11	0.1			
Units	ug/Kg	ug/Kg	T	%R	Q
PCB Congener					
8 - 2,4'-Dichlorobiphenyl (Cl2)	ND	2.1	5	42	
18 - 2,2',5-Trichlorobiphenyl (Cl3)	ND	ND			
28 - 2,4,4'-Trichlorobiphenyl (Cl3)	ND	3.1	5	62	
44 - 2,2',3,5'-Tetrachlorobiphenyl (Cl4)	ND	0.099 J			
49 - 2,2',4,5'-Tetrachlorobiphenyl (Cl4)	ND	ND			
52 - 2,2',5,5'-Tetrachlorobiphenyl (Cl4)	ND	3	5	60	
66 - 2,3',4,4'-Tetrachlorobiphenyl (Cl4)	ND	0.62			
87 - 2,2'3,4,5'-Pentachlorobiphenyl (Cl5)	ND	ND			
101 - 2,2',4,5,5'-Pentachlorobiphenyl (Cl5)	0.018 J	5.5	5	110	
105 - 2,3,3',4,4'-Pentachlorobiphenyl (Cl5)	ND	2.1			
118 - 2,3',4,4',5-Pentachlorobiphenyl (Cl5)	0.005 J	3.6			
128 - 2,2',3,3',4,4'-Hexachlorobiphenyl (Cl6)	ND	5.4	5	108	
138 - 2,2',3,4,4',5'-Hexachlorobiphenyl (Cl6)	0.05 J	16 E			
153 - 2,2',4,4',5,5'-Hexachlorobiphenyl (Cl6)	0.012 J	12	5	240	&
170 - 2,2',3,3',4,4',5-Heptachlorobiphenyl (Cl7)	ND	10			
180 - 2,2',3,4,4',5,5'-Heptachlorobiphenyl (Cl7)	0.0093 J	14	5	280	&
183 - 2,2',3,4,4',5',6-Heptachlorobiphenyl (Cl7)	ND	2.6			
184 - 2,2',3,4,4',6,6'-Heptachlorobiphenyl (Cl7)	ND	ND			
187 - 2,2',3,4',5,5',6-Heptachlorobiphenyl (Cl7)	0.004 J	5.4			
195 - 2,2',3,3',4,4',5,6-Octachlorobiphenyl (Cl8)	ND	1.4			
206 - 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl (Cl9)	0.0057 J	6.8	5	136	&
209 - 2,2',3,3',4,4',5,5',6,6'-Decachlorobiphenyl (Cl10)	ND	3.8	5	76	
Total PCB Congeners	0.21 J	190			
Dibromo-octafluoro-biphenyl	45	50			
103 - 2,2',4,5',6-Pentachlorobiphenyl	50	55			
198 - 2,2',3,3',4,5,5',6-Octachlorobiphenyl	62	77			

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Project Title : Battelle - CT River & Bridgeport, CT
Data Package: 3744
Data Table: BS-BSD - Not Surrogate Corrected

Field ID	Blank Spike Duplicate
Lab ID	DP-S-83BSD
Lab Batch	B1957
SDG	ADL3744
File	11160140.D
Sample Type	BSD
Matrix	SEDIMENT
Sample Size	20 g
Weight Basis	DRY
% Moisture (%)	NA
Associated Blank	DP-S-81PB
Field Date	11/05/01
Extract Date	11/05/01
Analysis Date	11/19/01
Date Received	11/05/01
Percent Solids	100
Dilution Factor	1
Percent Lipids	NA
Report Method	8081M PCB Congener

Min Reporting Limit	0.12						
Units	ug/Kg		T	%R	Q	RPD	Q
PCB Congener							
8 - 2,4'-Dichlorobiphenyl (Cl2)	2		5	40		4.9	
18 - 2,2',5-Trichlorobiphenyl (Cl3)		ND					
28 - 2,4,4'-Trichlorobiphenyl (Cl3)	3		5	60		3.3	
44 - 2,2',3,5'-Tetrachlorobiphenyl (Cl4)	0.055	J					
49 - 2,2',4,5'-Tetrachlorobiphenyl (Cl4)		ND					
52 - 2,2',5,5'-Tetrachlorobiphenyl (Cl4)	2.8		5	56		6.9	
66 - 2,3',4,4'-Tetrachlorobiphenyl (Cl4)	0.24						
87 - 2,2'3,4,5'-Pentachlorobiphenyl (Cl5)		ND					
101 - 2,2',4,5,5'-Pentachlorobiphenyl (Cl5)	4.1		5	82		29	
105 - 2,3,3',4,4'-Pentachlorobiphenyl (Cl5)	0.33						
118 - 2,3',4,4',5-Pentachlorobiphenyl (Cl5)	1.1						
128 - 2,2',3,3',4,4'-Hexachlorobiphenyl (Cl6)	3.3		5	66		48	&
138 - 2,2',3,4,4',5'-Hexachlorobiphenyl (Cl6)		ND					
153 - 2,2',4,4',5,5'-Hexachlorobiphenyl (Cl6)	4.5		5	90		91	&
170 - 2,2',3,3',4,4',5-Heptachlorobiphenyl (Cl7)	0.24						
180 - 2,2',3,4,4',5,5'-Heptachlorobiphenyl (Cl7)	3.6		5	72		120	&
183 - 2,2',3,4,4',5',6-Heptachlorobiphenyl (Cl7)	0.18						
184 - 2,2',3,4,4',6,6'-Heptachlorobiphenyl (Cl7)		ND					
187 - 2,2',3,4',5,5',6-Heptachlorobiphenyl (Cl7)	0.43						
195 - 2,2',3,3',4,4',5,6-Octachlorobiphenyl (Cl8)	0.022	J					
206 - 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl (Cl9)	3.4		5	68		67	&
209 - 2,2',3,3',4,4',5,5',6,6'-Decachlorobiphenyl (Cl10)	3.4		5	68		11	
Total PCB Congeners	65						
Dibromo-octafluoro-biphenyl	46						
103 - 2,2',4,5',6-Pentachlorobiphenyl	52						
198 - 2,2',3,3',4,5,5',6-Octachlorobiphenyl	68						

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Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3671
Data Table: MS-MSD - Not Surrogate Corrected

Field ID	AAK-008-C	AAK-008-CMS			
Lab ID	21A2590	21A2590MS			
Lab Batch	B1905	B1905			
SDG	ADL3671	ADL3671			
File	10110118.D	10110119.D			
Sample Type	N	MS			
Matrix	SEDIMENT	SEDIMENT			
Sample Size	24.6 g	24.57 g			
Weight Basis	DRY	DRY			
Associated Blank	DO-S-53PB	DO-S-53PB			
Field Date	09/05/01	09/05/01			
Extract Date	10/05/01	10/05/01			
Analysis Date	10/12/01	10/13/01			
Date Received	09/28/01	09/28/01			
Percent Solids	81.4	81.4			
Dilution Factor	1	1			
Percent Lipids	NA	NA			
Report Method	8082 - PCB Congener - GC-ECD	8082 - PCB Congener - GC-ECD			
Client Reporting Limit	1	1			
Min Reporting Limit	0.081	0.081			
Units	ug/Kg	ug/Kg	T	%R	Q
PCB Congener - GCECD					
8 - 2,4'-Dichlorobiphenyl	1 U	2.7	4.07	66	
18 - 2,2',5-Trichlorobiphenyl	1 U	1 U			
28 - 2,4,4'-Trichlorobiphenyl	1 U	3.6	4.07	88	
44 - 2,2',3,5'-Tetrachlorobiphenyl	1 U	1 U			
49 - 2,2',4,5'-Tetrachlorobiphenyl	1 U	1 U			
52 - 2,2',5,5'-Tetrachlorobiphenyl	1 U	3.3	4.07	80	
66 - 2,3',4,4'-Tetrachlorobiphenyl	1 U	1 U			
87 - 2,2',3,4,5'-Pentachlorobiphenyl	1 U	1 U			
101 - 2,2',4,5,5'-Pentachlorobiphenyl	1 U	3.6	4.07	90	
105 - 2,3,3',4,4'-Pentachlorobiphenyl	1 U	1 U			
118 - 2,3',4,4',5-Pentachlorobiphenyl	1 U	1 U			
128 - 2,2',3,3',4,4'-Hexachlorobiphenyl	1 U	3.8	4.07	93	
138 - 2,2',3,4,4',5'-Hexachlorobiphenyl	1 U	1 U			
153 - 2,2',4,4',5,5'-Hexachlorobiphenyl	1 U	4.1	4.07	94	
170 - 2,2',3,3',4,4',5-Heptachlorobiphenyl	1 U	1 U			
180 - 2,2',3,4,4',5,5'-Heptachlorobiphenyl	1 U	4.5	4.07	104	
183 - 2,2',3,4,4',5',6-Heptachlorobiphenyl	1 U	1 U			
184 - 2,2',3,4,4',6,6'-Heptachlorobiphenyl	1 U	1 U			
187 - 2,2',3,4',5,5',6-Heptachlorobiphenyl	1 U	1 U			
195 - 2,2',3,3',4,4',5,6-Octachlorobiphenyl	1 U	1 U			
206 - 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl	1 U	4.7	4.07	115	
209 - Decachlorobiphenyl	1 U	4.3	4.07	106	
Total PCB	ND	70			
Dibromo-octafluoro-biphenyl	79	81			
103 - 2,2',4,5',6-Pentachlorobiphenyl	109	125 &			
198 - 2,2',3,3',4,5,5',6-Octachlorobiphenyl	102	102			

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Environmental Chemistry and Forensics Unit

Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3671
Data Table: MS-MSD - Not Surrogate Corrected

Field ID	AAK-008-CMSD					
Lab ID	21A2590MSD					
Lab Batch	B1905					
SDG	ADL3671					
File	10110120.D					
Sample Type	MSD					
Matrix	SEDIMENT					
Sample Size	24.56 g					
Weight Basis	DRY					
Associated Blank	DO-S-53PB					
Field Date	09/05/01					
Extract Date	10/05/01					
Analysis Date	10/13/01					
Date Received	09/28/01					
Percent Solids	81.4					
Dilution Factor	1					
Percent Lipids	NA					
Report Method	8082 - PCB Congener - GC-ECD					
Client Reporting Limit	1					
Min Reporting Limit	0.1					
Units	ug/Kg	T	%R	Q	RPD	Q
PCB Congener - GCECD						
8 - 2,4'-Dichlorobiphenyl	2.6	4.07	64		3.1	
18 - 2,2',5-Trichlorobiphenyl	1 U					
28 - 2,4,4'-Trichlorobiphenyl	3.4	4.07	84		4.6	
44 - 2,2',3,5'-Tetrachlorobiphenyl	1 U					
49 - 2,2',4,5'-Tetrachlorobiphenyl	1 U					
52 - 2,2',5,5'-Tetrachlorobiphenyl	3.1	4.07	75		6.4	
66 - 2,3',4,4'-Tetrachlorobiphenyl	1 U					
87 - 2,2',3,4,5'-Pentachlorobiphenyl	1 U					
101 - 2,2',4,5,5'-Pentachlorobiphenyl	3.7	4.07	87		3.4	
105 - 2,3,3',4,4'-Pentachlorobiphenyl	1 U					
118 - 2,3',4,4',5-Pentachlorobiphenyl	1 U					
128 - 2,2',3,3',4,4'-Hexachlorobiphenyl	3.9	4.07	96		3.2	
138 - 2,2',3,4,4',5'-Hexachlorobiphenyl	1 U					
153 - 2,2',4,4',5,5'-Hexachlorobiphenyl	4	4.07	91		3.2	
170 - 2,2',3,3',4,4',5-Heptachlorobiphenyl	1 U					
180 - 2,2',3,4,4',5,5'-Heptachlorobiphenyl	4.2	4.07	97		7	
183 - 2,2',3,4,4',5',6-Heptachlorobiphenyl	1 U					
184 - 2,2',3,4,4',6,6'-Heptachlorobiphenyl	1 U					
187 - 2,2',3,4',5,5',6-Heptachlorobiphenyl	1 U					
195 - 2,2',3,3',4,4',5,6-Octachlorobiphenyl	1 U					
206 - 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl	4.4	4.07	108		6.3	
209 - Decachlorobiphenyl	4	4.07	98		7.8	
Total PCB	67					
Dibromo-octafluoro-biphenyl	76					
103 - 2,2',4,5',6-Pentachlorobiphenyl	85					
198 - 2,2',3,3',4,5,5',6-Octachlorobiphenyl	98					

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Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3671
Data Table: DUP - Not Surrogate Corrected

Field ID	AAK-006-C	AAK-006-CDUP		
Lab ID	21A2588	21A2588DUP		
Lab Batch	B1905	B1905		
SDG	ADL3671	ADL3671		
File	10110112.D	10110113.D		
Sample Type	N	DUP		
Matrix	SEDIMENT	SEDIMENT		
Sample Size	26.45 g	26.58 g		
Weight Basis	DRY	DRY		
Associated Blank	DO-S-53PB	DO-S-53PB		
Field Date	09/05/01	09/05/01		
Extract Date	10/05/01	10/05/01		
Analysis Date	10/12/01	10/12/01		
Date Received	09/28/01	09/28/01		
Percent Solids	88.1	88.1		
Dilution Factor	1	1		
Percent Lipids	NA	NA		
Report Method	8082 - PCB Congener - GC-ECD	8082 - PCB Congener - GC-ECD		
Client Reporting Limit	1	1		
Min Reporting Limit	0.088	0.087		
Units	ug/Kg	ug/Kg	RPD	Q
PCB Congener - GCECD				
8 - 2,4'-Dichlorobiphenyl	1 U	1 U		
18 - 2,2',5-Trichlorobiphenyl	1 U	1 U		
28 - 2,4,4'-Trichlorobiphenyl	1 U	1 U		
44 - 2,2',3,5'-Tetrachlorobiphenyl	1 U	1 U		
49 - 2,2',4,5'-Tetrachlorobiphenyl	1 U	1 U		
52 - 2,2',5,5'-Tetrachlorobiphenyl	1 U	1 U		
66 - 2,3',4,4'-Tetrachlorobiphenyl	1 U	1 U		
87 - 2,2',3,4,5'-Pentachlorobiphenyl	1 U	1 U		
101 - 2,2',4,5,5'-Pentachlorobiphenyl	1 U	1 U		
105 - 2,3,3',4,4'-Pentachlorobiphenyl	1 U	1 U		
118 - 2,3',4,4',5-Pentachlorobiphenyl	1 U	1 U		
128 - 2,2',3,3',4,4'-Hexachlorobiphenyl	1 U	1 U		
138 - 2,2',3,4,4',5'-Hexachlorobiphenyl	1 U	1 U		
153 - 2,2',4,4',5,5'-Hexachlorobiphenyl	1 U	1 U		
170 - 2,2',3,3',4,4',5-Heptachlorobiphenyl	1 U	1 U		
180 - 2,2',3,4,4',5,5'-Heptachlorobiphenyl	1 U	1 U		
183 - 2,2',3,4,4',5',6-Heptachlorobiphenyl	1 U	1 U		
184 - 2,2',3,4,4',6,6'-Heptachlorobiphenyl	1 U	1 U		
187 - 2,2',3,4',5,5',6-Heptachlorobiphenyl	1 U	1 U		
195 - 2,2',3,3',4,4',5,6-Octachlorobiphenyl	1 U	1 U		
206 - 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl	1 U	1 U		
209 - Decachlorobiphenyl	1 U	1 U		
Total PCB	ND	ND		
Dibromo-octafluoro-biphenyl	66	69		
103 - 2,2',4,5',6-Pentachlorobiphenyl	78	80		
198 - 2,2',3,3',4,5,5',6-Octachlorobiphenyl	85	91		

Arthur D. Little
Environmental Chemistry and Forensics Unit

Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3671
Data Table: SRM - Surrogate Corrected

Field ID	Standard Reference Material			
Lab ID	DO-S-56SRM			
Lab Batch	B1905			
SDG	ADL3671			
File	10110107.D			
Sample Type	SRM			
Matrix	SEDIMENT			
Sample Size	0.95 g			
Weight Basis	DRY			
Associated Blank	DO-S-53PB			
Field Date	10/05/01			
Extract Date	10/05/01			
Analysis Date	10/12/01			
Date Received	10/05/01			
Percent Solids	98.8			
Dilution Factor	1			
Percent Lipids	NA			
Report Method	8082 - PCB Congener - GC-ECD			
Client Reporting Limit	1			
Min Reporting Limit	9.14			
Units	ug/Kg	T	%D	Q
PCB Congener - GCECD				
8 - 2,4'-Dichlorobiphenyl	20.4	22.3	-8.52	
18 - 2,2',5-Trichlorobiphenyl	56.6	51	11	
28 - 2,4,4'-Trichlorobiphenyl	83.1	80.8	2.85	
44 - 2,2',3,5'-Tetrachlorobiphenyl	61.8	60.2	2.66	
49 - 2,2',4,5'-Tetrachlorobiphenyl	43.4	53	-18.1	
52 - 2,2',5,5'-Tetrachlorobiphenyl	68.4	79.4	-13.8	
66 - 2,3',4,4'-Tetrachlorobiphenyl	92.8	71.9	29.1	
87 - 2,2',3,4,5'-Pentachlorobiphenyl	30.2	29.9	1	
101 - 2,2',4,5,5'-Pentachlorobiphenyl	78	73.4	6.27	
105 - 2,3,3',4,4'-Pentachlorobiphenyl	26	24.5	6.12	
118 - 2,3',4,4',5-Pentachlorobiphenyl	69.1	58	19.1	
128 - 2,2',3,3',4,4'-Hexachlorobiphenyl	10.3	8.47	21.6	
138 - 2,2',3,4,4',5'-Hexachlorobiphenyl	79.6	62.1	28.2	
153 - 2,2',4,4',5,5'-Hexachlorobiphenyl	94.2	74	27.3	
170 - 2,2',3,3',4,4',5-Heptachlorobiphenyl	26.3	22.6	16.4	
180 - 2,2',3,4,4',5,5'-Heptachlorobiphenyl	54	44.3	21.9	
183 - 2,2',3,4,4',5',6-Heptachlorobiphenyl	13	12.19	6.64	
184 - 2,2',3,4,4',6,6'-Heptachlorobiphenyl	1 U			
187 - 2,2',3,4',5,5',6-Heptachlorobiphenyl	54.5	25.1	117	&
195 - 2,2',3,3',4,4',5,6-Octachlorobiphenyl	4.81	3.75	28.3	
206 - 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl	11.6	9.21	26	
209 - Decachlorobiphenyl	7.93	6.81	16.4	
Total PCB	1800			
Dibromo-octafluoro-biphenyl	99			
103 - 2,2',4,5',6-Pentachlorobiphenyl	120			
198 - 2,2',3,3',4,5,5',6-Octachlorobiphenyl	129 &			

Arthur D. Little
Environmental Chemistry and Forensics Unit

Project Title : Battelle - CT River & Bridgeport, CT
Data Package: 3744
Data Table: SRM - Surrogate Corrected

Field ID	Standard Reference Material-1944			
Lab ID	DP-S-84SRM			
Lab Batch	B1957			
SDG	ADL3744			
File	11160141.D			
Sample Type	SRM			
Matrix	SEDIMENT			
Sample Size	1.09 g			
Weight Basis	DRY			
% Moisture (%)	98.8			
Associated Blank	DP-S-81PB			
Field Date	11/05/01			
Extract Date	11/05/01			
Analysis Date	11/19/01			
Date Received	11/05/01			
Percent Solids	98.8			
Dilution Factor	1			
Percent Lipids	NA			
Report Method	8081M PCB Congener			
Min Reporting Limit	1.99			
Units	ug/Kg	T	%D	Q
PCB Congener				
8 - 2,4'-Dichlorobiphenyl (Cl2)	24.1	22.3	8.07	
18 - 2,2',5-Trichlorobiphenyl (Cl3)	54.1	51	6.08	
28 - 2,4,4'-Trichlorobiphenyl (Cl3)	73.9	80.8	-8.54	
44 - 2,2',3,5'-Tetrachlorobiphenyl (Cl4)	61	60.2	1.33	
49 - 2,2',4,5'-Tetrachlorobiphenyl (Cl4)	58.9	53	11.1	
52 - 2,2',5,5'-Tetrachlorobiphenyl (Cl4)	67.9	79.4	-14.5	
66 - 2,3',4,4'-Tetrachlorobiphenyl (Cl4)	94.4	71.9	31.3	
87 - 2,2'3,4,5'-Pentachlorobiphenyl (Cl5)	111	29.9	271	&
101 - 2,2',4,5,5'-Pentachlorobiphenyl (Cl5)	67.8	73.4	-7.63	
105 - 2,3,3',4,4'-Pentachlorobiphenyl (Cl5)	30.3	24.5	23.7	
118 - 2,3',4,4',5-Pentachlorobiphenyl (Cl5)	57.4	58	-1.03	
128 - 2,2',3,3',4,4'-Hexachlorobiphenyl (Cl6)	9.25	8.47	9.21	
138 - 2,2',3,4,4',5'-Hexachlorobiphenyl (Cl6)	76.8	62.1	23.7	
153 - 2,2',4,4',5,5'-Hexachlorobiphenyl (Cl6)	92.8	74	25.4	
170 - 2,2',3,3',4,4',5-Heptachlorobiphenyl (Cl7)	30.4	22.6	34.5	
180 - 2,2',3,4,4',5,5'-Heptachlorobiphenyl (Cl7)	48.4	44.3	9.26	
183 - 2,2',3,4,4',5',6-Heptachlorobiphenyl (Cl7)	14	12.19	14.8	
184 - 2,2',3,4,4',6,6'-Heptachlorobiphenyl (Cl7)	ND			
187 - 2,2',3,4',5,5',6-Heptachlorobiphenyl (Cl7)	63.8	25.1	154	&
195 - 2,2',3,3',4,4',5,6-Octachlorobiphenyl (Cl8)	2.48	3.75	-33.9	
206 - 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl (Cl9)	11.2	9.21	21.6	
209 - 2,2',3,3',4,4',5,5',6,6'-Decachlorobiphenyl (Cl10)	8.76	6.81	28.6	
Total PCB Congeners	1750			
Dibromo-octafluoro-biphenyl	53			
103 - 2,2',4,5',6-Pentachlorobiphenyl	59			
198 - 2,2',3,3',4,5,5',6-Octachlorobiphenyl	80			

Arthur D. Little
Environmental Chemistry and Forensics Unit

Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3671
Data Table: IRM - Surrogate Corrected

	Instrument Reference			
Field ID	Standard			
Lab ID	BW98IRM-1			
Lab Batch	NA			
SDG	ADL3671			
File	10030111.D			
Sample Type	IRM			
Matrix				
Sample Size	1 mL			
Weight Basis	WET			
Associated Blank	NA			
Field Date	12/02/00			
Extract Date	12/02/00			
Analysis Date	10/04/01			
Date Received	12/02/00			
Percent Solids	NA			
Dilution Factor	1			
Percent Lipids	NA			
Report Method	8082 - PCB Congener GC-ECD			
Client Reporting Limit	1			
Min Reporting Limit	1			
Units	ug/L	T	%D	Q
PCB Congener - GCECD				
8 - 2,4'-Dichlorobiphenyl	19.9			
18 - 2,2',5-Trichlorobiphenyl	22.4	20.1	11.4	
28 - 2,4,4'-Trichlorobiphenyl	21.8	19.9	9.55	
44 - 2,2',3,5'-Tetrachlorobiphenyl	22.2	19.9	11.6	
49 - 2,2',4,5'-Tetrachlorobiphenyl	1 U			
52 - 2,2',5,5'-Tetrachlorobiphenyl	21.9	19.7	11.2	
66 - 2,3',4,4'-Tetrachlorobiphenyl	22.5	20.1	11.9	
87 - 2,2',3,4,5'-Pentachlorobiphenyl	1 U			
101 - 2,2',4,5,5'-Pentachlorobiphenyl	21.9	19.8	10.6	
105 - 2,3,3',4,4'-Pentachlorobiphenyl	22.2	19.7	12.7	
118 - 2,3',4,4',5-Pentachlorobiphenyl	23.3			
128 - 2,2',3,3',4,4'-Hexachlorobiphenyl	22	20	10	
138 - 2,2',3,4,4',5'-Hexachlorobiphenyl	22.1	19.8	11.6	
153 - 2,2',4,4',5,5'-Hexachlorobiphenyl	21.8	19.8	10.1	
170 - 2,2',3,3',4,4',5-Heptachlorobiphenyl	22.2	19.7	12.7	
180 - 2,2',3,4,4',5,5'-Heptachlorobiphenyl	22.9	20	14.5	
183 - 2,2',3,4,4',5',6-Heptachlorobiphenyl	1 U			
184 - 2,2',3,4,4',6,6'-Heptachlorobiphenyl	1 U			
187 - 2,2',3,4',5,5',6-Heptachlorobiphenyl	22.1	19.7	12.2	
195 - 2,2',3,3',4,4',5,6-Octachlorobiphenyl	22.2	19.9	11.6	
206 - 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl	20.4	17.9	14	
209 - Decachlorobiphenyl	22.8	20	14	
Total PCB	793			
Dibromo-octafluoro-biphenyl	101			
103 - 2,2',4,5',6-Pentachlorobiphenyl	92			
198 - 2,2',3,3',4,5,5',6-Octachlorobiphenyl	96			

Arthur D. Little
Environmental Chemistry and Forensics Unit

Project Title : Battelle - CT River & Bridgeport, CT
Data Package: 3744
Data Table: IRM - Surrogate Corrected

	Instrument Reference			
Field ID	Standard			
Lab ID	W8250			
ADL ID	21A3064			
SDG	ADL3744			
File	11160109.D			
Sample Type	IRM			
Matrix	IRM			
Sample Size	1 mL			
Weight Basis	WET			
% Moisture (%)	NA			
Associated Blank	NA			
Field Date	10/25/01			
Extract Date	10/25/01			
Analysis Date	11/17/01			
Date Received	10/25/01			
Percent Solids	NA			
Dilution Factor	1			
Percent Lipids	NA			
Report Method	8081M PCB Congener			
Min Reporting Limit	1			
Units	ug/L	T	%D	Q
PCB Congener				
8 - 2,4'-Dichlorobiphenyl (Cl2)	20.6			
18 - 2,2',5-Trichlorobiphenyl (Cl3)	21.9	20.1	8.96	
28 - 2,4,4'-Trichlorobiphenyl (Cl3)	21.5	19.9	8.04	
44 - 2,2',3,5'-Tetrachlorobiphenyl (Cl4)	22.2	19.9	11.6	
49 - 2,2',4,5'-Tetrachlorobiphenyl (Cl4)	ND			
52 - 2,2',5,5'-Tetrachlorobiphenyl (Cl4)	22.2	19.7	12.7	
66 - 2,3',4,4'-Tetrachlorobiphenyl (Cl4)	21.1	20.1	4.98	
87 - 2,2'3,4,5'-Pentachlorobiphenyl (Cl5)	ND			
101 - 2,2',4,5,5'-Pentachlorobiphenyl (Cl5)	21.8	19.8	10.1	
105 - 2,3,3',4,4'-Pentachlorobiphenyl (Cl5)	20.8	19.7	5.58	
118 - 2,3',4,4',5-Pentachlorobiphenyl (Cl5)	20.1			
128 - 2,2',3,3',4,4'-Hexachlorobiphenyl (Cl6)	20.9	20	4.5	
138 - 2,2',3,4,4',5'-Hexachlorobiphenyl (Cl6)	22.2	19.8	12.1	
153 - 2,2',4,4',5,5'-Hexachlorobiphenyl (Cl6)	21.5	19.8	8.58	
170 - 2,2',3,3',4,4',5-Heptachlorobiphenyl (Cl7)	20.9	19.7	6.09	
180 - 2,2',3,4,4',5,5'-Heptachlorobiphenyl (Cl7)	21.5	20	7.5	
183 - 2,2',3,4,4',5',6-Heptachlorobiphenyl (Cl7)	ND			
184 - 2,2',3,4,4',6,6'-Heptachlorobiphenyl (Cl7)	ND			
187 - 2,2',3,4',5,5',6-Heptachlorobiphenyl (Cl7)	21.4	19.7	8.63	
195 - 2,2',3,3',4,4',5,6-Octachlorobiphenyl (Cl8)	20	19.9	0.502	
206 - 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl (Cl9)	18.6	17.9	3.91	
209 - 2,2',3,3',4,4',5,5',6,6'-Decachlorobiphenyl (Cl10)	21.1	20	5.5	
Total PCB Congeners	761			
Dibromo-octafluoro-biphenyl	90			
103 - 2,2',4,5',6-Pentachlorobiphenyl	87			
198 - 2,2',3,3',4,5,5',6-Octachlorobiphenyl	94			

Attachment 6

PAH Results

PAH – SEDIMENT QA/QC SUMMARY

PROJECT Deerfield River
PARAMETER PAH
LABORATORY Arthur D. Little, Inc
BATCH IDS B1905, B1957
MATRIX Sediment
SAMPLE CUSTODY Nine sediment samples were received from Battelle Memorial Institute (Duxbury) on September 28, 2001. All sample containers were intact and the sediment samples frozen. No deviations from normal protocols were noted. Analytical requirements were for selected PCB congeners by GC-ECD and selected PAHs by GC/MS. One extra sample was collected on 10/22/01 and analyzed on 11/17/01 for selected PAHs.

QA/QC DATA QUALITY OBJECTIVES:

	Reference Method	Blank	LCS/MS Recovery	SRM % Diff.	Surrogate Recovery	Relative Precision	Achieved Detection Limit (µg/kg DW)	Target Detection Limit (µg/kg DW)
PAH	General NS&T	<5xMDL (or associated samples >5× blank conc.)	40-120% (for 80% of analytes; MS conc. Must be >5× background)	≤30% different from range of certified values on average (for analytes >5× MDL, SIS corrected)	40-120%	≤30% (for analytes >5× MDL)	0.016 to 0.832	20

EXTRACTION METHOD: Sediment samples were extracted for PCB/PAHs following general NS&T methodologies. Approximately 50-g of well mixed, wet sediment was extracted three times with dichloromethane using sonication techniques. The third sonication extract was additionally extracted on a shaker table for 1-hour before decanting and combining it with the first two extracts. The combined extract was dried over anhydrous sodium sulfate, concentrated, cleaned with activated copper, and eluted through F-20 alumina column. The extract was concentrated further and submitted for HPLC cleanup with a pre-HPLC archive taken. The post-HPLC extract was concentrated, split quantitatively for GC/ECD and GC/MS analyses. The PAH extracts fortified with Recovery standards and the pre injection volume adjusted to 250uL. Samples were submitted and analyzed following general NS&T methods using a gas chromatograph/mass spectrophotometer (GC/MS) in single ion monitoring mode (SIM). Sample data were quantified by the method of internal standards, using the Recovery Internal Standard (RIS) compounds.

HOLDING TIMES:

Sediment samples for PAH and PCB analyses were received and stored frozen until extraction. The client gave no dates of field collection.

Batch	Extraction Date	Analysis Date
B1905	10/05/01	10/12/01 - 10/13/01
B1957	11/05/01	11/17/01

PAH – SEDIMENT QA/QC SUMMARY

DETECTION LIMITS:

Achieved detection limits were less than the required Target Detection Limits provided by Battelle. Achieved detection limits for PAHs are based on a 7 replicate MDL study and adjusted for the average dry weight of the batch.

Otherwise, censored PAH results for authentic samples and the PB are reported using Target Detection Limits (PAH 20 µug/kg, dry).

BLANKS:

A procedural blank (PB) was prepared with the analytical batch. Blanks were analyzed to ensure the sample extraction and analysis methods were free of contamination.

Batch B1905 - PAHs were undetected in the procedural blank at levels above the target DL.

Batch B1957 - PAHs were undetected in the procedural blank at levels above the target DL.

LABORATORY CONTROL SAMPLE (Blank Spike)

A laboratory control samples (LCS- Blank Spike, Blank Spike Duplicate) were prepared with the sediment analytical batch (B1905 and B1957). The percent recoveries of PAHs were calculated to measure data quality in terms of accuracy. The relative percent difference (RPD) between percent recoveries of PCBs in the BS and BSD were calculated to measure data quality in terms of precision.

Batch B1905–Spiked PAHs were recovered within the laboratory control limits specified by the method (40 – 120%). The Blank Spike recoveries ranged from 51 – 99% recovery and the Blank Spike Duplicate recoveries ranged from 48 - 99%. The RPDs of the BS/BSD ranged from 0 -10%.

Batch B1957 - Spiked PAHs were recovered within the laboratory control limits specified by the method (40 – 120%). The Blank Spike recoveries ranged from 61 - 97% recovery and the Blank Spike Duplicate recoveries ranged from 53 - 85%. Two RPDs were out of range (anthracene and benzo(a)pyrene) and the remainder ranged from 3.1 – 14%.

MATRIX SPIKES:

A matrix spike (MS)/matrix spike duplicate (MSD) sample was prepared with the analytical batch. The percent recoveries of PAHs in the MS/MSD were calculated to measure data quality in terms of accuracy. The relative percent difference (RPD) between percent recoveries of PAHs in the MS and MSD were calculated to measure data quality in terms of precision.

B1905, MS/MSD – Several percent recoveries and RPDs fall outside the laboratory control limits specified by the method (40 – 120% recovery and RPD≤30%, where concentration in MS >5x background). These outliers are as follows:

21A2590MS	147% Phenanthrene	
	147% Benzo[b]fluoranthene	
21A2590MS	197% Phenanthrene	
	221%Fluoranthene	RPD 100%
	197%Pyrene	RPD 67%
	147%Benzo[a]anthracene	RPD 40%
	147%Chrysene	RPD 40%
	221%Benzo[b]fluoranthene	RPD 40%

147%Benzo[a]pyrene	RPD 40%
138%Indeno[1,2,3-cd]pyrene	RPD 44%

Corrective Action - The background sample 21A2590 was visually inspected and found to be non-homogeneous mixture. A similar matrix was also noted in a sample duplicate of 21A2588 and RPD results indicate difficulties. Spiking levels were not high enough for the unanticipated variance in background concentrations. Surrogate recoveries for actual field samples and MS/MSD were all well within the control limits indicating extraction efficiency. BS/BSD results are acceptable and demonstrate batch precision. No further corrective action was taken.

Batch B1957 – No MS/MSD data is reported with this sample.

SURROGATES: Four surrogate compounds were added prior to extraction, including naphthalene-d8, acenapthene-d10, phenanthrene-d10 and benzo[a]pyrene-d12. The recovery of each surrogate compound was calculated to measure data quality in terms of accuracy (extraction efficiency).

Batch B1905 – All samples in this batch had surrogate recoveries within the required control limits (40-120%).

Batch B1957 - All samples in this batch had surrogate recoveries within the required control limits (40-120%).

REPLICATES: A sample duplicate was prepared with the analytical batch. The RPD between replicate analyses for PAHs was calculated to measure data quality in terms of precision.

Batch B1905 – 21A2588, 21A2588DUP – Several RPDs fall outside the laboratory control limits specified by the method (RPD≤30%). These outliers are as follows:

Phenanthrene	RPD 200%
Fluoranthene	RPD 200%
Pyrene	RPD 200%
Benzo[a]anthracene	RPD 200%
Chrysene	RPD 200%
Benzo[b]fluoranthene	RPD 200%
Benzo[k]fluoranthene	RPD 200%
Benzo[a]pyrene	RPD 200%
Benzo[e]pyrene	RPD 200%
Indeno[1,2,3-cd]pyrene	RPD 200%
Benzo[g,h,i]perylene	RPD 200%

Corrective Action - The background sample 21A25988 was visually inspected and found to be non-homogeneous mixture and is noted as such in the sample preparation records. RPD results indicate difficulties of variance in background concentrations. Surrogate recoveries for both the field sample and duplicate were within the control limits indicating extraction efficiency. BS/BSD results are acceptable and demonstrate batch precision. No further corrective action was taken.

Batch B1957 – No duplicate sample results reported with this sample.

PAH – SEDIMENT QA/QC SUMMARY

SRM:

A standard reference material (SRM, NIST 1491) was prepared with the analytical batch. The percent difference (%D) between the measured value and the certified range was calculated to measure data quality in terms of accuracy. *Note* – if the detected value fell within the certified range, then the PD is 0.0%.

Batch B1905 – SRM %Ds were within the control limits (≤30% from certified range, for analytes >5x MDL) for all certified PAHs except napthalene, with a %D of –52.2%. All remaining PDs ranged from 0 – 28.8%.

Corrective Action – Review of recoveries for napthalene in all other QC samples (BS/BSD, MS/MSD, IRM, NSC) showed results were within control limits. D8-napthalene surrogate recovery was acceptable (61%) and the situation was categorized as independent of the batch, and no additional corrective action was necessary. The suspected SRM (possibly an older standard) will be monitored for this loss and replaced if necessary.

Batch B1957 – SRM %Ds were within the control limits limits (≤30% from certified range, for analytes >5x MDL) for all certified PAHs except naphthalene (59.3%) and anthracene (37.8%).

Corrective Action – (see Batch 1905)

IRM:

An instrument reference standard (made from SRM, NIST 1493) is analyzed to check instrument performance with each analytical sequence. The percent difference (%D) between the measured value and the certified range was calculated to measure data quality in terms of accuracy.

Batch B1905 – IRM %Ds were within the control limits (≤30% from certified range, for analytes >5x MDL) for all certified PAHs. %Ds ranged from 0-10.9%.

Batch B1957 – IRM %Ds were within the control limits (≤30% from certified range, for analytes >5x MDL) for all certified PAHs. %Ds ranged from 0-12.8%.

Oil Reference Standard:

An Oil Reference Standard (ORS -made from a North Slope Crude) is analyzed to check instrument performance with each analytical sequence. The percent difference (%D) between the measured value and the historically certified range was calculated to measure data quality in terms of accuracy.

Batch B1905 – ORS %Ds were within the control limits (≤30% from certified range, for analytes >5x MDL) for all certified PAHs. %Ds ranged from 0-16.6%.

Miscellaneous documentation:

Per client request, a 20 ug/Kg-reporting limit was used instead of the calculated Minimum Reporting Limit (MRL). The calculated MRL is displayed in the spreadsheet header to demonstrate the Target reporting Limit (TRL) achieved.

Arthur D. Little
Environmental Chemistry and Forensics Unit

Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3666
Data Table: Main - Not Surrogate Corrected

Field ID	AAK-001-C	AAK-002-C	AAK-003-C	AAK-004-C
Lab ID	21A2583	21A2584	21A2585	21A2586
Lab Batch	B1905	B1905	B1905	B1905
SDG	NA	NA	NA	NA
File	S2454.D	S2455.D	S2456.D	S2457.D
Sample Type	N	N	N	N
Matrix	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT
Sample Size	40.32 g	43.35 g	44.16 g	41.74 g
Weight Basis	DRY	DRY	DRY	DRY
Associated Blank	DO-S-53PB	DO-S-53PB	DO-S-53PB	DO-S-53PB
Field Date	09/05/01	09/06/01	09/06/01	09/05/01
Extract Date	10/05/01	10/05/01	10/05/01	10/05/01
Analysis Date	10/10/01	10/10/01	10/11/01	10/11/01
Date Received	09/28/01	09/28/01	09/28/01	09/28/01
Percent Solids	80.5	86.5	87.8	83.3
Dilution Factor	1	1	1	1
Percent Lipids	NA	NA	NA	NA
Report Method	8270M	8270M	8270M	8270M
Client Reporting Limit	20	20	20	20
Min Reporting Limit	2.1	1.7	1.2	1.5
Units	ug/Kg	ug/Kg	ug/Kg	ug/Kg
Polynuclear Aromatic Hydrocarbons				
Naphthalene	20 U	20 U	20 U	20 U
1-Methylnaphthalene	20 U	20 U	20 U	20 U
2-Methylnaphthalene	20 U	20 U	20 U	20 U
2,6-Dimethylnaphthalene	20 U	20 U	20 U	20 U
Acenaphthylene	20 U	20 U	20 U	20 U
Acenaphthene	20 U	20 U	20 U	20 U
Biphenyl	20 U	20 U	20 U	20 U
Fluorene	20 U	20 U	20 U	20 U
Anthracene	27	20 U	20 U	20 U
Phenanthrene	90	53	20 U	24
1-Methylphenanthrene	20 U	20 U	20 U	20 U
Fluoranthene	210	110	31	43
Pyrene	190	95	39	48
Benzo[a]anthracene	110	54	20 U	26
Chrysene	110	56	22	26
Benzo[b]fluoranthene	120	68	22	30
Benzo[k]fluoranthene	40	22	20 U	20 U
Benzo[a]pyrene	96	52	20 U	24
Benzo[e]pyrene	67	39	20 U	20 U
Perylene	26	20 U	20 U	20 U
Indeno[1,2,3,-c,d]pyrene	58	33	20 U	20 U
Dibenzo[a,h]anthracene	20 U	20 U	20 U	20 U
Benzo[g,h,i]perylene	56	33	20 U	20 U
d8-Naphthalene	68	63	56	56
d10-Acenaphthene	76	73	68	64
d10-Phenanthrene	84	83	79	76
d12-Benzo[a]pyrene	78	79	72	70

Arthur D. Little
Environmental Chemistry and Forensics Unit

Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3666
Data Table: Main - Not Surrogate Corrected

Field ID	AAK-005-C	AAK-006-C	AAK-007-C	AAK-008-C
Lab ID	21A2587	21A2588	21A2589	21A2590
Lab Batch	B1905	B1905	B1905	B1905
SDG	NA	NA	NA	NA
File	S2458.D	S2459.D	S2461.D	S2463.D
Sample Type	N	N	N	N
Matrix	SEDIMENT	SEDIMENT	SEDIMENT	SEDIMENT
Sample Size	41.02 g	26.45 g	44.53 g	24.6 g
Weight Basis	DRY	DRY	DRY	DRY
Associated Blank	DO-S-53PB	DO-S-53PB	DO-S-53PB	DO-S-53PB
Field Date	09/05/01	09/05/01	09/05/01	09/05/01
Extract Date	10/05/01	10/05/01	10/05/01	10/05/01
Analysis Date	10/11/01	10/11/01	10/11/01	10/11/01
Date Received	09/28/01	09/28/01	09/28/01	09/28/01
Percent Solids	81.4	88.1	88.4	81.4
Dilution Factor	4	1	1	1
Percent Lipids	NA	NA	NA	NA
Report Method	8270M	8270M	8270M	8270M
Client Reporting Limit	20	20	20	20
Min Reporting Limit	1.5	2.2	1.1	2
Units	ug/Kg	ug/Kg	ug/Kg	ug/Kg
Polynuclear Aromatic Hydro				
Naphthalene	20 U	20 U	20 U	20 U
1-Methylnaphthalene	20 U	20 U	20 U	20 U
2-Methylnaphthalene	20 U	20 U	20 U	20 U
2,6-Dimethylnaphthalene	20 U	20 U	20 U	20 U
Acenaphthylene	42	20 U	20 U	20 U
Acenaphthene	20 U	20 U	20 U	20 U
Biphenyl	20 U	20 U	20 U	20 U
Fluorene	20 U	20 U	20 U	20 U
Anthracene	60	20 U	20 U	20 U
Phenanthrene	170	20 U	36	110
1-Methylphenanthrene	59	20 U	20 U	20 U
Fluoranthene	380 D	20 U	84	260
Pyrene	450 D	20 U	77	210
Benzo[a]anthracene	220	20 U	46	100
Chrysene	210	20 U	45	130
Benzo[b]fluoranthene	220	20 U	59	160
Benzo[k]fluoranthene	56	20 U	20 U	57
Benzo[a]pyrene	190	20 U	45	110
Benzo[e]pyrene	120	20 U	34	88
Perylene	48	20 U	20 U	33
Indeno[1,2,3,-c,d]pyrene	110	20 U	32	84
Dibenzo[a,h]anthracene	25	20 U	20 U	20 U
Benzo[g,h,i]perylene	100	20 U	29	82
d8-Naphthalene	60	64	73	62
d10-Acenaphthene	73	69	80	75
d10-Phenanthrene	79	76	87	87
d12-Benzo[a]pyrene	79	62	81	81

Arthur D. Little
Environmental Chemistry and Forensics Unit

Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3666
Data Table: Main - Not Surrogate Corrected

Field ID	AAK-009-C
Lab ID	21A2591
Lab Batch	B1905
SDG	NA
File	S2466.D
Sample Type	N
Matrix	SEDIMENT
Sample Size	43.07 g
Weight Basis	DRY
Associated Blank	DO-S-53PB
Field Date	09/05/01
Extract Date	10/05/01
Analysis Date	10/11/01
Date Received	09/28/01
Percent Solids	85.7
Dilution Factor	1
Percent Lipids	NA
Report Method	8270M
Client Reporting Limit	20
Min Reporting Limit	1.4
Units	ug/Kg

Polynuclear Aromatic Hydro	
Naphthalene	20 U
1-Methylnaphthalene	20 U
2-Methylnaphthalene	20 U
2,6-Dimethylnaphthalene	20 U
Acenaphthylene	20 U
Acenaphthene	20 U
Biphenyl	20 U
Fluorene	20 U
Anthracene	20 U
Phenanthrene	20 U
1-Methylphenanthrene	20 U
Fluoranthene	20 U
Pyrene	20 U
Benzo[a]anthracene	20 U
Chrysene	20 U
Benzo[b]fluoranthene	20 U
Benzo[k]fluoranthene	20 U
Benzo[a]pyrene	20 U
Benzo[e]pyrene	20 U
Perylene	20 U
Indeno[1,2,3,-c,d]pyrene	20 U
Dibenzo[a,h]anthracene	20 U
Benzo[g,h,i]perylene	20 U
d8-Naphthalene	61
d10-Acenaphthene	72
d10-Phenanthrene	81
d12-Benzo[a]pyrene	78

Arthur D. Little
Environmental Chemistry and Forensics Unit

Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3732
Data Table: Main Censored - Not Surrogate Corrected

Field ID	Sample 2A - R
Lab ID	W8250
Lab Batch	B1957
ADL ID	21A3064
File	S2962.D
Matrix	SEDIMENT
Sample Size	24.07 g
Weight Basis	DRY
Associated Blank	DP-S-81PB
Field Date	10/22/01
Extract Date	11/05/01
Analysis Date	11/17/01
Date Received	10/25/01
Report Method	8270M
Min Reporting Limit	4.6
Project Specific Reporting Limit	20
Units	ug/Kg

Polynuclear Aromatic Hydrocarbons	
Naphthalene	20 U
1-Methylnaphthalene	20 U
2-Methylnaphthalene	20 U
2,6-Dimethylnaphthalene	20 U
Acenaphthylene	20 U
Acenaphthene	20 U
Biphenyl	20 U
Fluorene	20 U
Anthracene	20 U
Phenanthrene	53
1-Methylphenanthrene	20 U
Fluoranthene	110
Pyrene	100
Benzo[a]anthracene	57
Chrysene	55
Benzo[b]fluoranthene	74
Benzo[k]fluoranthene	20
Benzo[a]pyrene	56
Benzo[e]pyrene	40
Perylene	20 U
Indeno[1,2,3,-c,d]pyrene	37
Dibenzo[a,h]anthracene	20 U
Benzo[g,h,i]perylene	34
d8-Naphthalene	68
d10-Acenaphthene	80
d10-Phenanthrene	98
d12-Benzo[a]pyrene	108

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Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3666
Data Table: BS-BSD - Not Surrogate Corrected

Field ID	Procedural Blank	Blank Spike			
Lab ID	DO-S-53PB	DO-S-54BS			
Lab Batch	B1905	B1905			
SDG	NA	NA			
File	S2450.D	S2451.D			
Sample Type	PB	BS			
Matrix	SEDIMENT	SEDIMENT			
Sample Size	30 g	30 g			
Weight Basis	DRY	DRY			
Associated Blank	NA	DO-S-53PB			
Field Date	10/05/01	10/05/01			
Extract Date	10/05/01	10/05/01			
Analysis Date	10/10/01	10/10/01			
Date Received	10/05/01	10/05/01			
Percent Solids	100	100			
Dilution Factor	1	1			
Percent Lipids	NA	NA			
Report Method	8270M	8270M			
Client Reporting Limit	20	20			
Min Reporting Limit	1.8	1.7			
Units	ug/Kg	ug/Kg	T	%R	Q
Polynuclear Aromatic Hydrocarbons					
Naphthalene	20 U	29	33.3	87	
1-Methylnaphthalene	20 U	20 U			
2-Methylnaphthalene	20 U	20 U			
2,6-Dimethylnaphthalene	20 U	20 U			
Acenaphthylene	20 U	21	33.3	63	
Acenaphthene	20 U	29	33.3	87	
Biphenyl	20 U	20 U			
Fluorene	20 U	29	33.3	87	
Anthracene	20 U	20 U	33.3	51	
Phenanthrene	20 U	31	33.3	93	
1-Methylphenanthrene	20 U	20 U			
Fluoranthene	20 U	33	33.3	99	
Pyrene	20 U	31	33.3	93	
Benzo[a]anthracene	20 U	28	33.3	84	
Chrysene	20 U	32	33.3	96	
Benzo[b]fluoranthene	20 U	31	33.3	93	
Benzo[k]fluoranthene	20 U	32	33.3	96	
Benzo[a]pyrene	20 U	20 U	33.3	54	
Benzo[e]pyrene	20 U	20 U			
Perylene	20 U	20 U			
Indeno[1,2,3,-c,d]pyrene	20 U	28	33.3	84	
Dibenzo[a,h]anthracene	20 U	30	33.3	90	
Benzo[g,h,i]perylene	20 U	30	33.3	90	
d8-Naphthalene	72	75			
d10-Acenaphthene	72	75			
d10-Phenanthrene	80	80			
d12-Benzo[a]pyrene	43	42			

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Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3666
Data Table: BS-BSD - Not Surrogate Corrected

Field ID	Blank Spike Duplicate						
Lab ID	DO-S-55BSD						
Lab Batch	B1905						
SDG	NA						
File	S2452.D						
Sample Type	BSD						
Matrix	SEDIMENT						
Sample Size	30 g						
Weight Basis	DRY						
Associated Blank	DO-S-53PB						
Field Date	10/05/01						
Extract Date	10/05/01						
Analysis Date	10/10/01						
Date Received	10/05/01						
Percent Solids	100						
Dilution Factor	1						
Percent Lipids	NA						
Report Method	8270M						
Client Reporting Limit	20						
Min Reporting Limit	1.7						
Units	ug/Kg		T	%R	Q	RPD	Q
Polynuclear Aromatic Hydro							
Naphthalene	29		33.3	87		0	
1-Methylnaphthalene	20	U					
2-Methylnaphthalene	20	U					
2,6-Dimethylnaphthalene	20	U					
Acenaphthylene	20	U	33.3	57		10	
Acenaphthene	28		33.3	84		3.5	
Biphenyl	20	U					
Fluorene	30		33.3	90		3.4	
Anthracene	20	U	33.3	48		6.1	
Phenanthrene	31		33.3	93		0	
1-Methylphenanthrene	20	U					
Fluoranthene	33		33.3	99		0	
Pyrene	32		33.3	96		3.2	
Benzo[a]anthracene	27		33.3	81		3.6	
Chrysene	33		33.3	99		3.1	
Benzo[b]fluoranthene	31		33.3	93		0	
Benzo[k]fluoranthene	32		33.3	96		0	
Benzo[a]pyrene	20	U	33.3	51		5.7	
Benzo[e]pyrene	20	U					
Perylene	20	U					
Indeno[1,2,3,-c,d]pyrene	28		33.3	84		0	
Dibenzo[a,h]anthracene	30		33.3	90		0	
Benzo[g,h,i]perylene	30		33.3	90		0	
d8-Naphthalene	75						
d10-Acenaphthene	74						
d10-Phenanthrene	79						
d12-Benzo[a]pyrene	40						

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Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3732
Data Table: BS-BSD - Not Surrogate Corrected

Field ID	Procedural Blank	Blank Spike			
Lab ID	DP-S-81PB	DP-S-82BS			
Lab Batch	B1957	B1957			
SDG	ADL3732	ADL3732			
File	S2937.D	S2938.D			
Matrix	SEDIMENT	SEDIMENT			
Sample Size	20 g	20 g			
Weight Basis	DRY	DRY			
Associated Blank	NA	DP-S-81PB			
Field Date	11/05/01	11/05/01			
Extract Date	11/05/01	11/05/01			
Analysis Date	11/15/01	11/15/01			
Date Received	11/05/01	11/05/01			
Report Method	8270M	8270M			
Min Reporting Limit	2.8	2.5			
Project Specific Reporting Limit	20	20			
Units	ug/Kg	ug/Kg	T	%R	Q
Polynuclear Aromatic Hydrocarbons					
Naphthalene	0.56 J	29	50	57	
1-Methylnaphthalene	0.13 J	0.15 JB			
2-Methylnaphthalene	0.23 J	0.3 JB			
2,6-Dimethylnaphthalene	ND	ND			
Acenaphthylene	0.038 J	27	50	54	
Acenaphthene	0.031 J	33	50	66	
Biphenyl	0.055 J	0.073 JB			
Fluorene	0.073 J	38	50	76	
Anthracene	0.013 J	33	50	66	
Phenanthrene	0.36 J	45	50	89	
1-Methylphenanthrene	0.023 J	0.056 JB			
Fluoranthene	0.081 J	52	50	104	
Pyrene	0.068 J	50	50	100	
Benzo[a]anthracene	ND	47	50	94	
Chrysene	ND	53	50	106	
Benzo[b]fluoranthene	ND	50	50	100	
Benzo[k]fluoranthene	ND	55	50	110	
Benzo[a]pyrene	ND	36	50	72	
Benzo[e]pyrene	ND	ND			
Perylene	ND	ND			
Indeno[1,2,3,-c,d]pyrene	ND	41	50	82	
Dibenzo[a,h]anthracene	ND	45	50	90	
Benzo[g,h,i]perylene	0.25 J	46	50	92	
d8-Naphthalene	69	61			
d10-Acenaphthene	69	70			
d10-Phenanthrene	78	97			
d12-Benzo[a]pyrene	45	79			

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Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3732
Data Table: BS-BSD - Not Surrogate Corrected

Field ID	Blank Spike Duplicate					
Lab ID	DP-S-83BSD					
Lab Batch	B1957					
SDG	ADL3732					
File	S2939.D					
Matrix	SEDIMENT					
Sample Size	20 g					
Weight Basis	DRY					
Associated Blank	DP-S-81PB					
Field Date	11/05/01					
Extract Date	11/05/01					
Analysis Date	11/15/01					
Date Received	11/05/01					
Report Method	8270M					
Min Reporting Limit	2.9					
Project Specific Reporting Limit	20					
Units	ug/Kg	T	%R	Q	RPD	Q
Polynuclear Aromatic Hydrocarbons						
Naphthalene	31	50	61		6.8	
1-Methylnaphthalene	0.18 JB					
2-Methylnaphthalene	0.33 JB					
2,6-Dimethylnaphthalene	ND					
Acenaphthylene	23	50	46		16	
Acenaphthene	32	50	64		3.1	
Biphenyl	0.079 JB					
Fluorene	35	50	70		8.2	
Anthracene	23	50	46		36	&
Phenanthrene	40	50	79		12	
1-Methylphenanthrene	0.11 J					
Fluoranthene	45	50	90		14	
Pyrene	44	50	88		13	
Benzo[a]anthracene	41	50	82		14	
Chrysene	49	50	98		7.8	
Benzo[b]fluoranthene	45	50	90		10	
Benzo[k]fluoranthene	50	50	100		9.5	
Benzo[a]pyrene	26	50	52		32	&
Benzo[e]pyrene	ND					
Perylene	ND					
Indeno[1,2,3,-c,d]pyrene	36	50	72		13	
Dibenzo[a,h]anthracene	40	50	80		12	
Benzo[g,h,i]perylene	40	50	80		14	
d8-Naphthalene	66					
d10-Acenaphthene	69					
d10-Phenanthrene	85					
d12-Benzo[a]pyrene	53					

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Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3666
Data Table: MS-MSD - Not Surrogate Corrected

Field ID	AAK-008-C	AAK-008-CMS			
Lab ID	21A2590	21A2590MS			
Lab Batch	B1905	B1905			
SDG	NA	NA			
File	S2463.D	S2464.D			
Sample Type	N	MS			
Matrix	SEDIMENT	SEDIMENT			
Sample Size	24.6 g	24.57 g			
Weight Basis	DRY	DRY			
Associated Blank	DO-S-53PB	DO-S-53PB			
Field Date	09/05/01	09/05/01			
Extract Date	10/05/01	10/05/01			
Analysis Date	10/11/01	10/11/01			
Date Received	09/28/01	09/28/01			
Percent Solids	81.4	81.4			
Dilution Factor	1	1			
Percent Lipids	NA	NA			
Report Method	8270M	8270M			
Client Reporting Limit	20	20			
Min Reporting Limit	2	2			
Units	ug/Kg	ug/Kg	T	%R	Q
Polynuclear Aromatic Hydrocarbons					
Naphthalene	20 U	30	40.7	69	
1-Methylnaphthalene	20 U	20 U			
2-Methylnaphthalene	20 U	20 U			
2,6-Dimethylnaphthalene	20 U	20 U			
Acenaphthylene	20 U	39	40.7	86	
Acenaphthene	20 U	40	40.7	89	
Biphenyl	20 U	20 U			
Fluorene	20 U	49	40.7	104	
Anthracene	20 U	57	40.7	98	
Phenanthrene	110	170	40.7	147	&
1-Methylphenanthrene	20 U	20 U			
Fluoranthene	260	290	40.7	74	
Pyrene	210	250	40.7	98	
Benzo[a]anthracene	100	140	40.7	98	
Chrysene	130	170	40.7	98	
Benzo[b]fluoranthene	160	220	40.7	147	&
Benzo[k]fluoranthene	57	75	40.7	44	
Benzo[a]pyrene	110	150	40.7	98	
Benzo[e]pyrene	88	88			
Perylene	33	32			
Indeno[1,2,3,-c,d]pyrene	84	120	40.7	88	
Dibenzo[a,h]anthracene	20 U	56	40.7	96	
Benzo[g,h,i]perylene	82	120	40.7	93	
d8-Naphthalene	62	63			
d10-Acenaphthene	75	78			
d10-Phenanthrene	87	91			
d12-Benzo[a]pyrene	81	87			

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Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3666
Data Table: MS-MSD - Not Surrogate Corrected

Field ID	AAK-008-CMSD
Lab ID	21A2590MSD
Lab Batch	B1905
SDG	NA
File	S2465.D
Sample Type	MSD
Matrix	SEDIMENT
Sample Size	24.56 g
Weight Basis	DRY
Associated Blank	DO-S-53PB
Field Date	09/05/01
Extract Date	10/05/01
Analysis Date	10/11/01
Date Received	09/28/01
Percent Solids	81.4
Dilution Factor	1
Percent Lipids	NA
Report Method	8270M
Client Reporting Limit	20
Min Reporting Limit	2.5

Units	ug/Kg		T	%R	Q	RPD	Q
Polynuclear Aromatic Hydro							
Naphthalene	32		40.7	74		7	
1-Methylnaphthalene	20	U					
2-Methylnaphthalene	20	U					
2,6-Dimethylnaphthalene	20	U					
Acenaphthylene	42		40.7	93		7.8	
Acenaphthene	39		40.7	86		3.4	
Biphenyl	20	U					
Fluorene	49		40.7	104		0	
Anthracene	58		40.7	101		3	
Phenanthrene	190		40.7	197	&	29	
1-Methylphenanthrene	20	U					
Fluoranthene	350		40.7	221	&	100	&
Pyrene	290		40.7	197	&	67	&
Benzo[a]anthracene	160		40.7	147	&	40	&
Chrysene	190		40.7	147	&	40	&
Benzo[b]fluoranthene	250		40.7	221	&	40	&
Benzo[k]fluoranthene	79		40.7	54		20	
Benzo[a]pyrene	170		40.7	147	&	40	&
Benzo[e]pyrene	100						
Perylene	39						
Indeno[1,2,3,-c,d]pyrene	140		40.7	138	&	44	&
Dibenzo[a,h]anthracene	56		40.7	96		0	
Benzo[g,h,i]perylene	130		40.7	118		24	
d8-Naphthalene	61						
d10-Acenaphthene	74						
d10-Phenanthrene	82						
d12-Benzo[a]pyrene	78						

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Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3666
Data Table: DUP - Not Surrogate Corrected

Field ID	AAK-006-C	AAK-006-CDUP		
Lab ID	21A2588	21A2588DUP		
Lab Batch	B1905	B1905		
SDG	NA	NA		
File	S2459.D	S2460.D		
Sample Type	N	DUP		
Matrix	SEDIMENT	SEDIMENT		
Sample Size	26.45 g	26.58 g		
Weight Basis	DRY	DRY		
Associated Blank	DO-S-53PB	DO-S-53PB		
Field Date	09/05/01	09/05/01		
Extract Date	10/05/01	10/05/01		
Analysis Date	10/11/01	10/11/01		
Date Received	09/28/01	09/28/01		
Percent Solids	88.1	88.1		
Dilution Factor	1	1		
Percent Lipids	NA	NA		
Report Method	8270M	8270M		
Client Reporting Limit	20	20		
Min Reporting Limit	2.2	2.2		
Units	ug/Kg	ug/Kg	RPD	Q
Polynuclear Aromatic Hydrocarbons				
Naphthalene	20 U	20 U		
1-Methylnaphthalene	20 U	20 U		
2-Methylnaphthalene	20 U	20 U		
2,6-Dimethylnaphthalene	20 U	20 U		
Acenaphthylene	20 U	20 U		
Acenaphthene	20 U	20 U		
Biphenyl	20 U	20 U		
Fluorene	20 U	20 U		
Anthracene	20 U	20 U		
Phenanthrene	20 U	90	200	&
1-Methylphenanthrene	20 U	20 U		
Fluoranthene	20 U	160	200	&
Pyrene	20 U	140	200	&
Benzo[a]anthracene	20 U	62	200	&
Chrysene	20 U	57	200	&
Benzo[b]fluoranthene	20 U	77	200	&
Benzo[k]fluoranthene	20 U	22	200	&
Benzo[a]pyrene	20 U	58	200	&
Benzo[e]pyrene	20 U	38	200	&
Perylene	20 U	20 U		
Indeno[1,2,3,-c,d]pyrene	20 U	40	200	&
Dibenzo[a,h]anthracene	20 U	20 U		
Benzo[g,h,i]perylene	20 U	36	200	&
d8-Naphthalene	64	61		
d10-Acenaphthene	69	66		
d10-Phenanthrene	76	76		
d12-Benzo[a]pyrene	62	71		

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Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3666
Data Table: SRM - Surrogate Corrected

	Standard Reference			
Field ID	Material			
Lab ID	DO-S-56SRM			
Lab Batch	B1905			
SDG	NA			
File	S2453.D			
Sample Type	SRM			
Matrix	SEDIMENT			
Sample Size	0.95 g			
Weight Basis	DRY			
Associated Blank	DO-S-53PB			
Field Date	10/05/01			
Extract Date	10/05/01			
Analysis Date	10/10/01			
Date Received	10/05/01			
Percent Solids	98.8			
Dilution Factor	1			
Percent Lipids	NA			
Report Method	8270M			
Client Reporting Limit	20			
Min Reporting Limit	228			
Units	ug/Kg	T	%D	Q
Polynuclear Aromatic Hydrocarbons				
Naphthalene	789	1650	-52.2	&
1-Methylnaphthalene	370			
2-Methylnaphthalene	354			
2,6-Dimethylnaphthalene	307			
Acenaphthylene	515			
Acenaphthene	437			
Biphenyl	144			
Fluorene	630			
Anthracene	1260	1770	-28.8	
Phenanthrene	5490	5270	4.17	
1-Methylphenanthrene	1650			
Fluoranthene	9580	8920	7.4	
Pyrene	10200	9700	5.15	
Benzo[a]anthracene	4890	4720	3.6	
Chrysene	5650	5900	-4.24	
Benzo[b]fluoranthene	6100	5960	2.35	
Benzo[k]fluoranthene	1870	2300	-18.7	
Benzo[a]pyrene	3970	4300	-7.67	
Benzo[e]pyrene	3700	3280	12.8	
Perylene	1130	1170	-3.42	
Indeno[1,2,3,-c,d]pyrene	2650	2780	-4.68	
Dibenzo[a,h]anthracene	704	759	-7.25	
Benzo[g,h,i]perylene	2840	2840	0	
d8-Naphthalene	61			
d10-Acenaphthene	73			
d10-Phenanthrene	89			
d12-Benzo[a]pyrene	82			

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Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3732
Data Table: SRM - Not Surrogate Corrected

Field ID	Standard Reference Material-1944			
Lab ID	DP-S-84SRM			
Lab Batch	B1957			
SDG	ADL3732			
File	S2940.D			
Matrix	SEDIMENT			
Sample Size	1.09 g			
Weight Basis	DRY			
Associated Blank	DP-S-81PB			
Field Date	11/05/01			
Extract Date	11/05/01			
Analysis Date	11/15/01			
Date Received	11/05/01			
Report Method	8270M			
Min Reporting Limit	99.8			
Project Specific Reporting Limit	20			
Units	ug/Kg	T	%D	Q
Polynuclear Aromatic Hydrocarbons				
Naphthalene	672	1650	-59.3	&
1-Methylnaphthalene	277			
2-Methylnaphthalene	307			
2,6-Dimethylnaphthalene	280			
Acenaphthylene	726			
Acenaphthene	325			
Biphenyl	115			
Fluorene	497			
Anthracene	1100	1770	-37.8	&
Phenanthrene	4270	5270	-19	
1-Methylphenanthrene	1190			
Fluoranthene	7260	8920	-18.6	
Pyrene	7390	9700	-23.8	
Benzo[a]anthracene	3720	4720	-21.2	
Chrysene	4630	4860	-4.73	
Benzo[b]fluoranthene	4600	3870	18.9	
Benzo[k]fluoranthene	1780	2300	-22.6	
Benzo[a]pyrene	3060	4300	-28.8	
Benzo[e]pyrene	2890	3280	-11.9	
Perylene	909	1170	-22.3	
Indeno[1,2,3,-c,d]pyrene	2120	2780	-23.7	
Dibenzo[a,h]anthracene	525	424	23.8	
Benzo[g,h,i]perylene	2270	2840	-20.1	
d8-Naphthalene	62			
d10-Acenaphthene	77			
d10-Phenanthrene	96			
d12-Benzo[a]pyrene	97			

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Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3666
Data Table: IRM - Surrogate Corrected

	Instrument Reference				
Field ID	Standard				
Lab ID	CA12IRM-1				
Lab Batch	NA				
SDG	NA				
File	S2438.D				
Sample Type	IRM				
Matrix	IRM				
Sample Size	0.1	mL			
Weight Basis	WET				
Associated Blank	NA				
Field Date	09/10/01				
Extract Date	09/10/01				
Analysis Date	10/10/01				
Date Received	09/10/01				
Percent Solids	NA				
Dilution Factor	1				
Percent Lipids	NA				
Report Method	8270M				
Client Reporting Limit	20				
Min Reporting Limit	250				
Units	ug/L		T	%D	Q
Polynuclear Aromatic Hydrocarbons					
Naphthalene	6740		6890	-2.18	
1-Methylnaphthalene	8960		8300	7.95	
2-Methylnaphthalene	9320				
2,6-Dimethylnaphthalene	7380		7200	2.5	
Acenaphthylene	6280		6960	-9.77	
Acenaphthene	6500		7280	-10.7	
Biphenyl	7300		7000	4.28	
Fluorene	6260		7270	-13.9	
Anthracene	6970		7820	-10.9	
Phenanthrene	6960		7010	-0.713	
1-Methylphenanthrene	7180		7000	2.57	
Fluoranthene	5880		5910	-0.508	
Pyrene	5870		5890	-0.34	
Benzo[a]anthracene	3390		3590	-5.57	
Chrysene	7030		7030	0	
Benzo[b]fluoranthene	5290		5250	0.762	
Benzo[k]fluoranthene	5770		5570	3.59	
Benzo[a]pyrene	6580		6790	-3.09	
Benzo[e]pyrene	5830		5620	3.74	
Perylene	7550		7120	6.04	
Indeno[1,2,3,-c,d]pyrene	6110		6290	-2.86	
Dibenzo[a,h]anthracene	5520		5180	6.56	
Benzo[g,h,i]perylene	5270		5290	-0.378	
d8-Naphthalene	103				
d10-Acenaphthene	100				
d10-Phenanthrene	101				
d12-Benzo[a]pyrene	94				

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Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3732
Data Table: IRM - Not Surrogate Corrected

	Instrument Reference			
Field ID	Standard			
Lab ID	CA12IRM-1			
SDG	ADL3732			
File	S2902.D			
Matrix	IRM			
Sample Size	0.1 mL			
Weight Basis	WET			
Associated Blank	NA			
Field Date	09/10/01			
Extract Date	09/10/01			
Analysis Date	11/14/01			
Date Received	09/10/01			
Report Method	8270M			
Min Reporting Limit	250			
Project Specific Reporting Limit	250			
Units	ug/L	T	%D	Q
Polynuclear Aromatic Hydrocarbons				
Naphthalene	6680	6890	-3.05	
1-Methylnaphthalene	8930	8300	7.59	
2-Methylnaphthalene	8310			
2,6-Dimethylnaphthalene	7440	7200	3.33	
Acenaphthylene	6360	6960	-8.62	
Acenaphthene	6470	7280	-11.1	
Biphenyl	7300	7000	4.28	
Fluorene	6340	7270	-12.8	
Anthracene	7030	7820	-10.1	
Phenanthrene	7220	7010	3	
1-Methylphenanthrene	7320			
Fluoranthene	5900	5910	-0.169	
Pyrene	5850	5890	-0.679	
Benzo[a]anthracene	3440	3590	-4.16	
Chrysene	7230	7030	2.84	
Benzo[b]fluoranthene	5370	5250	2.28	
Benzo[k]fluoranthene	5860	5570	5.21	
Benzo[a]pyrene	6450	6790	-5.01	
Benzo[e]pyrene	5860	5620	4.27	
Perylene	7460	7120	4.78	
Indeno[1,2,3,-c,d]pyrene	5830	6290	-7.31	
Dibenzo[a,h]anthracene	5340	5180	3.09	
Benzo[g,h,i]perylene	5100	5290	-3.59	
d8-Naphthalene	106			
d10-Acenaphthene	102			
d10-Phenanthrene	102			
d12-Benzo[a]pyrene	100			

Arthur D. Little
Environmental Chemistry and Forensics Unit

Project Title : BATTELLE - DEERFIELD RIVER
Data Package: 3666
Data Table: ORS - Surrogate Corrected

Field ID	Oil Reference Standard			
Lab ID	BY32ORS-1			
Lab Batch	NA			
SDG	NA			
File	S2439.D			
Sample Type	ORS			
Matrix	OIL			
Sample Size	5.12 mg			
Weight Basis	OIL			
Associated Blank	NA			
Field Date	03/21/01			
Extract Date	03/21/01			
Analysis Date	10/10/01			
Date Received	03/21/01			
Percent Solids	NA			
Dilution Factor	1			
Percent Lipids	NA			
Report Method	8270M			
Client Reporting Limit	20			
Min Reporting Limit	4.88			
Units	mg/Kg	T	%D	Q
Polynuclear Aromatic Hydrocarbons				
Naphthalene	771	710	8.59	
1-Methylnaphthalene	1140 E			
2-Methylnaphthalene	1220			
2,6-Dimethylnaphthalene	518			
Acenaphthylene	20 U			
Acenaphthene	20 U			
Biphenyl	232	214	8.41	
Fluorene	111	95.2	16.6	
Anthracene	20 U			
Phenanthrene	282	260	8.46	
1-Methylphenanthrene	203			
Fluoranthene	20 U			
Pyrene	20 U	13.4	0	NA
Benzo[a]anthracene	20 U			
Chrysene	52.9	49.2	7.52	
Benzo[b]fluoranthene	20 U	7.62	0	NA
Benzo[k]fluoranthene	20 U			
Benzo[a]pyrene	20 U			
Benzo[e]pyrene	20 U	12.4	0	NA
Perylene	20 U			
Indeno[1,2,3,-c,d]pyrene	20 U			
Dibenzo[a,h]anthracene	20 U			
Benzo[g,h,i]perylene	20 U	3.18	0	NA
d8-Naphthalene	98			
d10-Acenaphthene	98			
d10-Phenanthrene	96			
d12-Benzo[a]pyrene	96			

APPENDIX 4 - Incremental Analysis

Green River Restoration
Cost Effectiveness/Incremental Cost Analysis

January 10, 2006

Prepared by
New England District
U.S. Army Corps of Engineers
696 Virginia Road
Concord, Massachusetts

Green River Restoration Project
Incremental/Cost Effectiveness Analysis

Table of Contents

Introduction

An Incremental Analysis was conducted in order to quantify the habitat benefits that would accrue for each of the proposed restoration alternatives. A quantification of benefits is necessary in order determine the most effective restoration plan. The recommended alternative is based on the alternative(s) which would most cost effectively optimize the habitat for the target species to be restored (i.e. anadromous fish), while minimizing any negative effects to existing habitat and species (lacustrine and riverine fish, and wetland species). The ten restoration alternatives for the Green River Habitat Restoration project are discussed in the Environmental Assessment. The method used for evaluating the Green River involves the examination of three primary habitat types that define the existing ecosystem (i.e. study area). These include:

- Riverine habitat, which exists in the reaches of the river between each of the dams, upstream and downstream of their impoundments.
- Lacustrine habitat; which has been created by each of the dams (i.e. their impoundments) and extends upstream from each of them; and
- Wetland habitat, which is located at various locations along the edges of the river or adjacent to the river, and may be hydraulically dependent upon the water levels of the river and/or the impoundments. The primary wetland examined in this study is located in the oxbow area adjacent to the Mill Street Dam impoundment (i.e. upstream from the dam).

These habitat types are discussed further in Appendix A. In conducting this Incremental Analysis, these habitat types are evaluated in terms of positive or negative changes that might be expected with each of the possible restoration alternatives. In evaluating the changes that would occur, it is possible that implementation of some of the restoration alternatives will decrease one habitat type while increasing another (i.e. by the removal of dams, the amount of lacustrine habitat formed by the impoundment will be reduced, however the riverine habitat will improve). The method used evaluates changes in each habitat type for each alternative, and quantifies the total amount of change for each of them in order to determine the one(s) that produce(s) the most habitat benefits per unit cost.

Incremental Model

Each of the primary habitat types is evaluated according to a set of specific habitat criteria. These criteria are treated as variables that can change with each of the alternatives. The change can be positive, negative or neutral (zero). These criteria include measures of habitat quality and/or suitability that are necessary to support a given species or groups of species common to that specific habitat type (i.e. in this case the habitat types would be lacustrine, riverine and wetland). Within each specific habitat type, the criteria are further broken down into two categories, general criteria, and species-specific criteria. The general criteria are those basic elements within a specific habitat which are necessary to support life. For aquatic habitats, which include lacustrine and riverine, they include water temperature, dissolved oxygen, turbidity, substrate and its ability to support food items, as well as several other parameters necessary to support fish species in general.

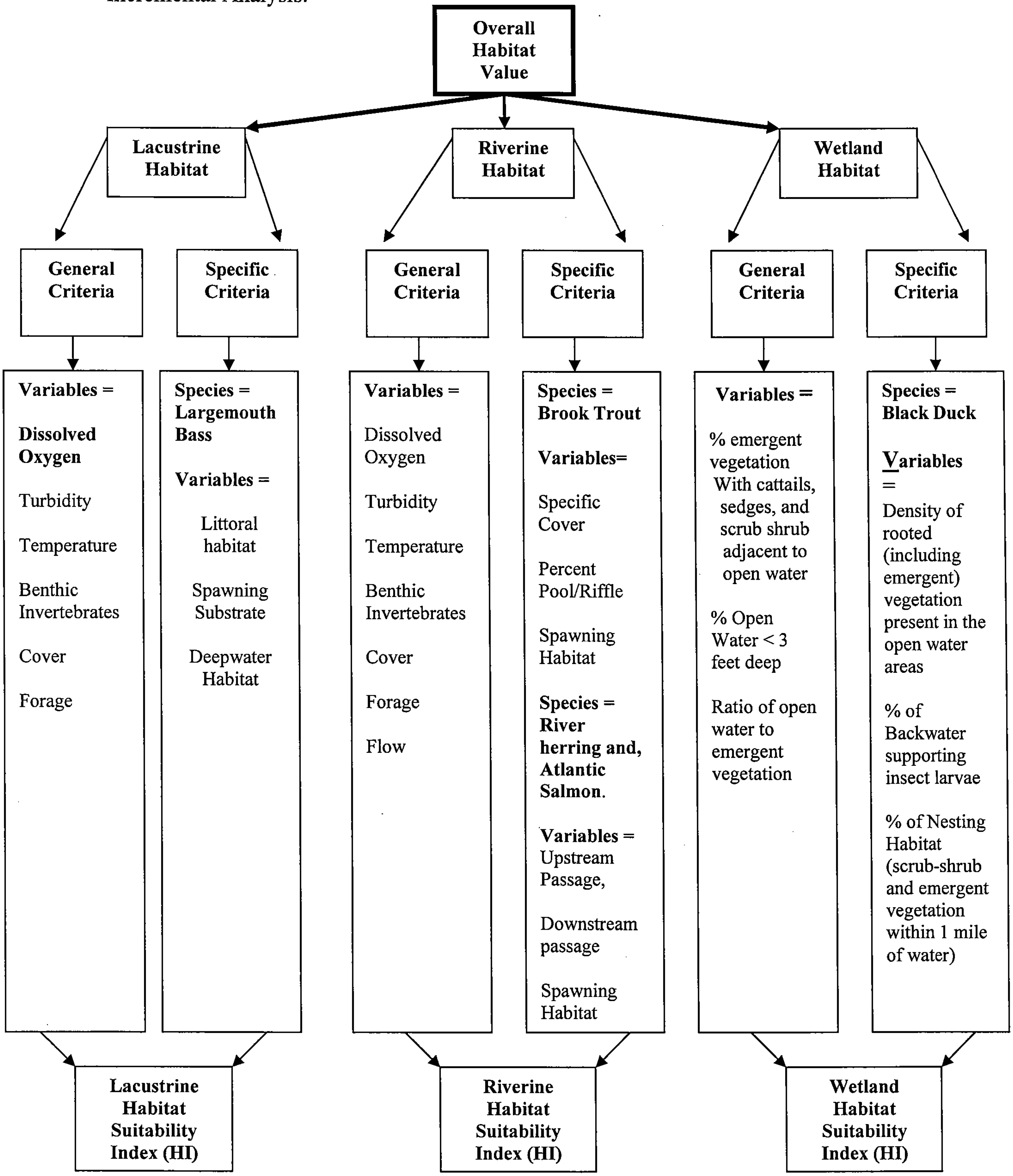
The second category, which is the species-specific criteria, includes (in addition to the general survival criteria noted earlier) those essential for reproduction, growth and continued survival of a particular target species. For example, for an anadromous fish species these criteria would include upstream passage, downstream passage and spawning habitat, since they would be necessary for a specific anadromous fish to be restored and sustained in a habitat given that the basic water quality requirements were met. A list of these criteria for each habitat type is given in Appendix A. A generalized chart of the habitat evaluation model is presented in Figure 1.

Method

When evaluating a habitat, each of the criteria (i.e. variables) is assigned a value between 0 and 1, depending upon its quality and/or ability to support aquatic life within its particular habitat type. A value of 0 would be given for a variable which is unsuitable for aquatic life or for the survival, growth and reproduction of a particular species, and a value of 1 would be given to that variable if it was optimal for supporting aquatic life or preferred by a species for survival, growth and/or reproduction. Values in between would be given for habitat that would be acceptable but not necessarily optimal (in various degrees). These values are then combined for each habitat type to obtain an index for that specific habitat type ranging between 0 and 1 (1 being considered optimal). This is known as a Habitat Suitability Index (HI). The method for obtaining a specific HI for a given habitat is discussed in detail in Appendix A, and usually involves combining both the general habitat criteria and the specific habitat criteria, by using a combination of a geometric mean (for the general criteria), and a weighted mean (for the specific criteria). Then using a geometric mean, the two sets of criteria are combined to calculate the final HI for the given habitat type. Figure 1 also shows diagrammatically the relationship of these criteria to the HI.

The rationale for this method of habitat value combination is also discussed in Appendix A. Generally, the reason for using a geometric mean for the essential criteria and a weighted mean for the species specific criteria is to indicate the unsuitability of the habitat for the support of any target species if any one of the general criteria is unsuitable. This would be indicated by a value of 0 for that particular variable. By using a geometric mean, the value of that particular habitat would be 0 even if only one general criterion were unsuitable (a value of 0), thereby showing the necessity of all the essential (i.e. general) criteria being suitable in order to support life. The species-specific criteria use a weighted mean, since even if the habitat did not specifically support that target species; it may still be able to support other species in general (if the general criteria are suitable).

Figure 1. Generalized Diagram of Habitat Evaluation Model used for Green River Incremental Analysis.

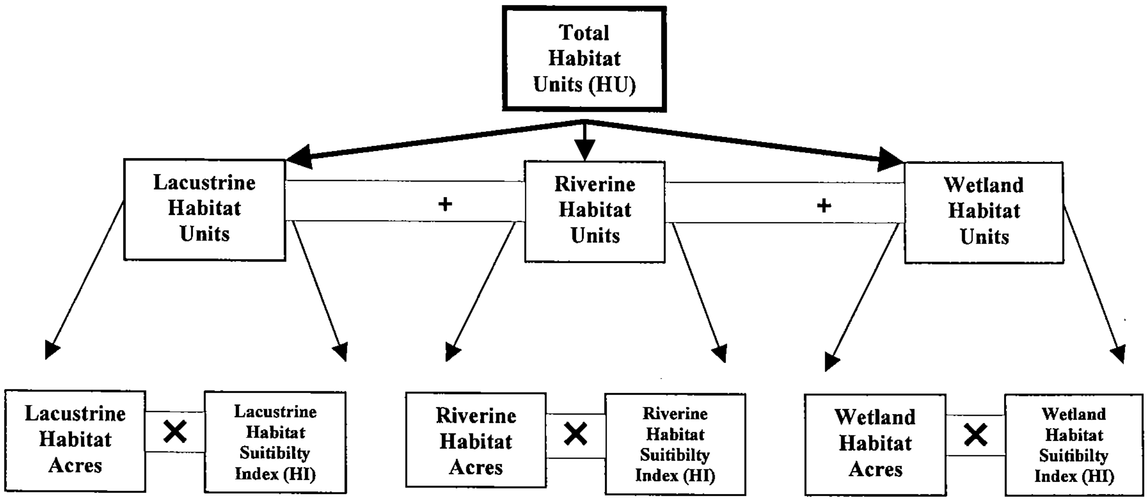


Therefore, if one of the species-specific variables is unsuitable (value of 0), the HI will not necessarily be 0 for the entire habitat since the essential criteria are being met. The formula for calculating the HI for each habitat type is given in Appendix A.

In order to measure the benefits that would result from the implementation of each alternative for the entire ecosystem, the individual HI's, which are calculated for each habitat (i.e. either Lacustrine, Riverine or Wetland), are multiplied by the number of acres of that specific habitat to obtain the number of Habitat Units (HU). The HU's for each of the three habitat types are then summed to obtain a total number of HU's for each alternative. This provides an overall total value of the ecosystem (expressed in total HU's) for each of the alternatives analyzed. The formula for calculating Habitat Units is presented in Appendix A. The total number of HU's for each alternative and the incremental changes in Habitat Units between all alternatives relative to their cost(s), are further examined in order to determine the most cost effective and "best buy" option(s). This Incremental Cost Analysis is presented in Appendix B.

For the Green River, the total acreages calculated for each of the habitat types is presented below. These acres of each habitat type are then multiplied by the HI that was calculated for that particular habitat, in order to obtain the total Habitat Units of that habitat. The Habitat Units from each habitat type are then added to obtain the total habitat units for each of the alternatives. A detailed discussion on how each of the habitat criteria within each habitat type changes with each of the alternatives can be found in Appendix A. The discussion includes the reasons for the changes and why each variable was assigned its specific value for each of the alternatives. Any subjectivity in the assigned values is minimized by the consistent application of evaluation criteria across all alternatives. A spreadsheet, which contains the calculations for the individual Habitat Suitability Indices for each habitat type, and the calculated Habitat Units for each of the alternatives is also located in Appendix A (Attachment 1). A general diagram of the relationship of Total Habitat Units to the Habitat Suitability Indices calculated for each habitat type is presented in Figure 2. The information that includes the acreages as well as the total Habitat Units for each of the restoration alternatives is presented in the following pages.

Figure 2. Generalized Diagram of Formula for Calculating Total Habitat Units from Individual Habitat Suitability Indices Acreages.



Acreages

Lacustrine Habitat - 11.10 acres (includes the acreages of the impoundments behind the Wiley & Russell Dam (approximately 4.48 acres) and Mill Street Dam (6.62 acres).

Riverine Habitat - The total river miles for the study area is approximately 19.1, which includes all of the Green River dams. Using mean widths of the river measured along the entire study course, the total acreage for the river acres was calculated as 156.76 acres. This includes the acreages of the Wiley & Russell and Mill Street impoundments as well, since these will remain part of the river in the fish ladder alternatives.

Wetland/Waterfowl Habitat -There are approximately 15 acres of wetlands interspersed with uplands adjacent to the Mill Street impoundment, some under the influence of the existing water level (which is the spillway elevation). It is assumed that any waterfowl that occupy these wetlands also utilize the open water of the Mill Street impoundment, which as noted above is approximately 6.62 acres. Therefore a total of 21.47 acres of wetland/waterfowl habitat exists in the vicinity of Mill Street Dam. This acreage also includes the fringing wetlands along the riverbank in that area.

It should be noted that for the dam removal alternatives (including various combinations of dam removal and fish ladder construction), if a dam is removed, the number of acres of lacustrine habitat created by the impoundments is reduced when the impoundments drain. Therefore, there are less acres of that particular habitat, which when multiplied by the particular HI for that alternative, may cause a decrease in the Habitat Units.

Habitat Units

Using the acreages calculated above for each habitat type, habitat units were calculated by multiplying them by the respective Habitat Suitability Index (HI) obtained for each alternative. As noted above, various alternatives involve the reduction of overall acreages, and the separation of acreages in order to represent habitat improvements that affect specific areas. The actual calculations as well as the total Habitat Units are presented in the spreadsheet noted above (Attachment 1 to Appendix A) and also on page 38 of Appendix A.

Alternative 1, No Action

Lacustrine HU's = 4.65.
Riverine HU's = 71.91
Wetland/Waterfowl HU's = 18.52

Total Habitat Units =95.08

Alternative 2, Removal of 2 Dams with Fish Ladders at 2

Lacustrine HU's = 1.96.
Riverine HU's = 121.38
Wetland/Waterfowl HU's = 4.92

Total Habitat Units = 128.26

Alternative 3, Fish Ladders at all 4 Dams

Lacustrine HU's = 4.72.
Riverine HU's = 97.08
Wetland/Waterfowl HU's = 18.52

Total Habitat Units = 120.32

Alternative 4, Rock Ramp at Wiley & Russell, Removal of Mill St and Fish ladders

Lacustrine HU's = 3.01
Riverine HU's = 111.02
Wetland/Waterfowl HU's = 4.92

Total Habitat Units = 118.94

Alternative 5 – Fish Ladder at Wiley & Russell, Removal of Mill St. and Fish Ladders at Swimming Pool and Pumping Station

Lacustrine HU's = 3.01
Riverine HU's = 108.23
Wetland/Waterfowl HU's =4.92

Total Habitat Units =116.16

Alternative 6- Dam Removal at Wiley & Russell and Mill Street, Fish Ladders at 2 upstream Dams, and in-stream Habitat improvements at Wiley & Russell and Leyden Woods

Lacustrine HU's = 1.99
Riverine HU's = 121.59
Wetland/Waterfowl HU's =4.92

Total Habitat Units =128.50

Alternative7 –Fish Ladder at all Dams. In-stream work for Habitat Restoration at Leyden Woods

Lacustrine HU's = 4.79.
Riverine HU's = 97.14
Wetland/Waterfowl HU's =18.52

Total Habitat Units =120.45

Alternative 8- Rock Ramp at Wiley & Russell, remove Mill Street and Fish Ladders at Swimming Pool and Pumping Station, In-Stream work at Leyden Woods.

Lacustrine HU's = 3.05
Riverine HU's = 111.07
Wetland/Waterfowl HU's = 4.92

Total Habitat Units =119.04

Alternative 9 - Fish Ladder at Wiley & Russell, Remove Mill Street and Fish Ladder at Swimming Pool and Pumping Station, In stream work for Habitat Restoration at Leyden Woods

Lacustrine HU's = 3.05
Riverine HU's = 108.29
Wetland/Waterfowl HU's = 4.92

Total Habitat Units =116.26

Alternative 10 - Rock Ramp at Wiley & Russell, Fish Ladder at Mill Street, Swimming Pool and Water Supply Dam, and In stream work for Habitat Restoration at Leyden Woods.

Lacustrine HU's = 4.79
Riverine HU's = 97.15
Wetland/Waterfowl HU's = 18.52

Total Habitat Units = 120.46

Incremental Cost Analysis

In this section, the costs of the alternative restoration plans are compared to the environmental benefits within the framework of an incremental cost analysis, to determine the most cost effective alternatives and the best buy alternatives. An incremental cost analysis examines how the costs of additional units of environmental output increase as the level of environmental output increases. For this analysis, the environmental outputs are measured in habitat units. The analysis was conducted in accordance with IWR Report 95-R-1, Evaluation of Environmental Investments Procedures Manual-Interim: Cost Effectiveness and Incremental Cost Analyses, May 1995; and ER 1105-2-100, Planning Guidance Notebook, Section 3-5, Ecosystem Restoration, April 2000.

An incremental cost curve can be identified by displaying cost effective solutions. Cost effective solutions are those increments that result in the same output, or number of habitat units, for the least cost. An increment is cost effective if there are no others that cost less and provide the same number of habitat units. Alternatively, for a given increment cost, there will be no other increments that provide more habitat units

Nine alternative plans were examined in the incremental analysis for the Deerfield River study. The goal of the incremental analysis is to identify which alternative plans are best buy plans, Best buy plans are a subset of cost effective plans, and are those plans that have the lowest cost per habitat unit when compared to the no action plan. Alternative 1 is the no action plan. With no Federal action, the habitat in the study area will remain as it is currently. The remaining alternatives consist of various combinations of dam removal, construction of fish ladders, and in-stream habitat improvements, all of which will improve the habitat quality to varying degrees. Alternative 2 consists of the removal of the Wiley & Russell and Mill Street dams, and construction of fish ladders at the Swimming Pool and Pumping Station dams. Alternative 3 consists of constructing fish ladders at all four dams. Alternative 4 consists of constructing a rock ramp at the Wiley & Russell dam, removing the Mill St. dam, and constructing fish ladders at the Swimming Pool and Pumping Station dams. Alternative 5 consists of constructing fish ladders at the Wiley & Russell, Swimming Pool and Pumping Station dams, and removing the Mill St. dam. Alternative 6 consists of the improvements of Alternative 2 plus in-stream habitat restoration downstream of the Mill St. dam and at Leydon Woods. Alternative 7 consists of Alternative 3 plus habitat restoration at Leydon Woods. Alternative 8 consists of Alternative 4 plus habitat restoration at Leydon Woods. Alternative 9 consists of Alternative 5 plus habitat restoration at Leydon Woods. Alternative 10 consists of constructing a rock ramp at the Wiley & Russell dam, and fish ladders at the remaining 3 dams.

The estimated costs of the alternatives analyzed are shown below in Table 1. Costs shown reflect total project costs, and include initial construction cost, Engineering and Design (E&D), Supervision and Administration (S&A), real estate costs, and interest during construction (IDC). IDC was calculated using the FY 05 Federal Interest rate of 5 3/8 % and assuming a one year construction period for all alternatives with payment in 12 equal increments; It should be noted that IDC is an economic cost, not a financial cost and thus does not need to be cost-shared.

Table 1
Estimated Project Costs
Deerfield River/Green River Habitat Restoration Project

Alternative		**Cost Estimate**
1 No Action		$0
2 Remove Wiley & Russell Dam		$145,500
Remove Mill St. Dam		$148,500
Fish Ladder at Swimming Pool Dam		$123,400
Fish Ladder at Pumping Station Dam		$207,300
Real Estate		$98,000
E&D		$250,000
S&A		$140,000
	sub-total	$1,112,700
	IDC	$28,000
	Total	$1,140,700
3 Fish Ladder at Wiley & Russell Dam		$225,500
Fish Ladder at Mill St. Dam		$213,800
Fish Ladder at Swimming Pool Dam		$123,400
Fish Ladder at Pumping Station Dam		$207,300
Real Estate		$98,000

E&D		$250,000
S&A		$140,000
	sub-total	$1,258,100
	IDC	$31,600
	Total	$1,289,700
4 Rock ramp fishway at Wiley & Russell Dam		$133,900
Remove Mill St. Dam		$148,500
Fish Ladder at Swimming Pool Dam		$123,400
Fish Ladder at Pumping Station Dam		$207,300
Real Estate		$98,000
E&D		$250,000
S&A		$140,000
	sub-total	$1,101,200
	IDC	$27,700
	Total	$1,128,900
5 Fish Ladder at Wiley & Russell Dam		$225,500
Remove Mill St. Dam		$148,500
Fish Ladder at Swimming Pool Dam		$123,400
Fish Ladder at Pumping Station Dam		$207,300
Real Estate		$98,000
E&D		$250,000
S&A		$140,000
	sub-total	$1,192,800
	IDC	$30,000
	Total	$1,222,800
6 Remove Wiley & Russell Dam		$145,500
Remove Mill St. Dam		$148,500
Fish Ladder at Swimming Pool Dam		$123,400
Fish Ladder at Pumping Station Dam		$207,300
Habitat Restoration downstream of Mill St. dam		$29,700
Habitat Restoration at Leydon Woods		$17,400
Real Estate		$114,000
E&D		$250,000
S&A		$140,000
	sub-total	$1,175,900
	IDC	$29,500
	Total	$1,205,400
7 Fish Ladder at Wiley & Russell Dam		$225,500
Fish Ladder at Mill St. Dam		$213,800
Fish Ladder at Swimming Pool Dam		$123,400
Fish Ladder at Pumping Station Dam		$207,300
Habitat Restoration at Leydon Woods		$17,400
Real Estate		$114,000
E&D		$250,000
S&A		$140,000
	sub-total	$1,291,500
	IDC	$32,400
	Total	$1,324,000

8	Rock ramp fishway at Wiley & Russell Dam		$133,900
	Remove Mill St. Dam		$148,500
	Fish Ladder at Swimming Pool Dam		$123,400
	Fish Ladder at Pumping Station Dam		$207,300
	Habitat Restoration at Leydon Woods		$17,400
	Real Estate		$114,000
	E&D		$250,000
	S&A		$140,000
		sub-total	$1,134,700
		IDC	$28,500
		Total	$1,163,200
9	Fish Ladder at Wiley & Russell Dam		$225,500
	Remove Mill St. Dam		$148,500
	Fish Ladder at Swimming Pool Dam		$123,400
	Fish Ladder at Pumping Station Dam		$207,300
	Habitat Restoration at Leydon Woods		$17,400
	Real Estate		$114,000
	E&D		$250,000
	S&A		$140,000
		sub-total	$1,226,300
		IDC	$30,800
		Total	$1,257,100
10	Rock ramp fishway at Wiley & Russell Dam		$133,900
	Fish Ladder at Mill St. Dam		$213,800
	Fish Ladder at Swimming Pool Dam		$123,400
	Fish Ladder at Pumping Station Dam		$207,300
	Real Estate		$98,000
	E&D		$250,000
	S&A		$140,000
		sub-total	$1,166,500
		IDC	$29,300
		Total	$1,195,800

The total cost and acres of habitat created for each alternative plan are shown in Table 2. For this incremental analysis, the habitat units for each alternative were based on an analysis of the lacustrine habitat, riverine habitat, and wetland/waterfowl habitat units that would exist with each plan, as detailed in the Environmental Assessment and in Appendix A.

Table 2
Costs and Benefits of Alternative Plans
Deerfield River/Green River Habitat Restoration Project

Alt. Plan	Description	Total Project Cost ($000's)	Benefit in Habitat Units (HU)
1	No Action	0	95.08
2	Remove Wiley & Russell and Mill St. dams; Fish Ladders at Swimming Pool and Water Supply Dams	1,140.7	128.26
3	Fish Ladders at all 4 dams	1,289.7	120.32
4	Rock Ramp at Wiley & Russell; Remove Mill St. dam; Fish Ladders at Swimming Pool and Pumping Station dams	1,128.9	118.94
5	Fish Ladders at Wiley & Russell, Swimming Pool and Pumping Station dams; remove Mill St. dam	1,222.8	116.16
6	Remove Wiley & Russell and Mill St. dams; Fish Ladders at Swimming Pool and Water Supply Dams; Habitat restoration downstream of Mill St. dam and at Leydon Woods	1,205.4	128.50
7	Fish Ladders at all 4 dams; Habitat Restoration at Leydon Woods	1,324.0	120.45
8	Rock Ramp at Wiley & Russell; Remove Mill St. dam; Fish Ladders at Swimming Pool and Pumping Station dams; Habitat restoration at Leydon Woods	1,163.2	119.04
9	Fish Ladders at Wiley & Russell, Swimming Pool and Pumping Station dams; remove Mill St. dam; Habitat restoration at Leydon Woods	1,257.1	116.26
10	Rock Ramp at Wiley & Russell; Fish Ladders at Mill St., Swimming Pool, and Pumping Station Dams	1,195.8	120.46

In conducting the incremental analysis, the Corps of Engineers software program "IWR-PLAN" was used. The first step of the analysis was to identify cost effective plans. An alternative is considered cost effective if no other plans provide the same or greater number of habitat units for less cost. The incremental analysis identified four cost effective plans. Alternatives 1, 2, 4 and 6 were identified as cost effective. Table 3, below, shows the alternatives arranged in order of increasing habitat units provided. Alternatives 3 and 7 are not cost effective because Alternative 10 provides slightly more HU at a lower cost. Alternatives 5 and 9 are not cost effective because Alternative 4 provides more output at a lower cost. Alternatives 8 and 10 are not cost effective because Alternative 2 provides more output at a lower cost.

Table 3
Alternatives Arranged by Increasing Habitat Units
Deerfield River/Green River Habitat Restoration Project

Alternative	Total Project Cost ($000's)	Benefit in Habitat Units (HU)	Average Cost ($/HU)	Incremental HU
1	0.00	95.08		
5	1,222.80	116.16	10.53	21.08
9	1,257.10	116.26	10.81	0.10
4	1,128.90	118.94	9.49	2.68
8	1,163.20	119.04	9.77	0.10
3	1,289.70	120.32	10.72	1.28
7	1,324.00	120.45	10.99	0.13
10	1,195.80	120.46	9.93	0.01
2	1,140.70	128.26	8.89	7.80
6	1,205.40	128.50	9.38	0.24

The second step of the incremental analysis is to identify the best buy plans. Best buy plans are a subset of cost effective plans, and are those plans that have the lowest cost per habitat unit when compared to the no action plan. A plan is considered a best buy plan if there are no other plans that will give the same or more output at a lower incremental cost when all plans are compared to the no action alternative. It was determined that Alternative 4 is not a best buy plan because Alternative 2 has a lower incremental cost per incremental habitat unit and greater HU in comparison to the no action plan. This left three plans as best buy plans, Alternatives 1, 2 and 6.

The best buy plans, Alternatives 1, 2 and 6, make up the incremental cost curve. Table 4 shows the incremental output, incremental cost, and incremental cost per habitat unit for each best buy plan. The graph of the incremental cost curve is also shown below.

Table 4
Incremental Cost Curve
Deerfield River/Green River

	Alternative	Output (HU)	Cost ($000)	Incr. Output (HU)	Incr. Cost ($000)	Incr. Cost/ Incr. Output ($000's/HU)
1	No Action	95.08	0	-	-	-
2	Remove Wiley & Russell and Mill St. dams; Fish Ladders at Swimming Pool and Water Supply Dams	128.26	1,140.70	33.18	1,140.70	34.379
6	Remove Wiley & Russell and Mill St. dams; Fish Ladders at Swimming Pool and Water Supply Dams; Habitat Resotration downstream of Mill St. dam and at Leydon Woods	128.5	1,205.40	0.24	64.7	269.583

In the incremental cost curve, incremental cost per unit increases with output, or habitat units. Development of the incremental cost curve facilitates the selection of the best alternative. The question that is asked at each increment is: "Is the additional gain in environmental benefit worth the additional cost?" In this study, the incremental cost curve consists of three points represented by Alternatives 1, 2 and 6. Alternative 2 creates 33.18 additional units of habitat over the no action alternative (Alt. 1), and Alternative 6 creates an additional 0.24 units of habitat over Alternative 2, with an incremental cost of $64,700. However, Alternative 2 has an incremental cost per incremental habitat unit of $34,379, whereas Alternative 6 has an incremental cost per incremental habitat unit of $269,583, which points to Alternative 2 being the most cost efficient plan.

Conclusions and Recommendation

This incremental analysis determined that Alternatives 1, 2 and 6 are best buy plans. Alternatives 1, 2, 4 and 6 were identified as cost effective. In comparing the best buy plans alternatives, Alternative 6 yields the most total habitat, but has a much higher incremental cost per incremental HU than Alternative 2. Alternative 2 provides nearly as much habitat at a greatly lower incremental cost per incremental HU. Alternative 4 is also cost effective and may be implemented if factors not considered in the incremental analysis warrant.

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Appendix A

Green River Aquatic Ecosystem Restoration Project
Incremental Analysis

(Detailed Description and Methodology)

This incremental analysis was conducted in order to quantify the habitat benefits associated with providing fish passage in the Green River beyond the Wiley & Russell, Mill Street, Town Swimming Pool and Pumping Station dams and compare the various alternatives for accomplishing this. The historical habitat before the construction of these dams was a natural free flowing river with its anadromous and riverine fish populations. However, the construction of dams has resulted in the loss of historic anadromous fish runs due to obstruction of their upstream migration, and by impounding the water behind them, portions of the habitat have changed from riverine to lacustrine, resulting in localized reductions in the riverine fish community, which have been replaced by a lacustrine fish community (to varying degrees). In addition, several acres of wetland exist above the Mill Street Dam in the vicinity of an old oxbow that may be partially supported by the water level of the Mill Street Dam impoundment. These wetlands provide habitat for a variety of aquatic, avian and terrestrial wildlife species.

The two dams upstream from Mill Street include the Town Swimming Pool Dam, and the Pumping Station Dam (Water Supply Dam). The impoundments behind both of these dams are currently used for municipal purposes (i.e. the Swimming Pool Dam is used for public recreation, and the Water Supply Dam is used as a Municipal Drinking water supply). In addition to all of these dams preventing the upstream (and downstream) migrations of diadromous fish, fish habitat in the Green River has been negatively affected by severe streambank erosion. In some sections, these eroded streambanks are providing additional fine sediment to the river, which is carried downstream and deposited in the impoundments behind the dams. During times of higher flows, these sediments can be mobilized and washed into the downstream sections of the Green and Deerfield Rivers, potentially covering up sand and gravel bottom substrate, and suffocating benthic food organisms used by riverine fish. Therefore, in addition to the alternatives of providing fish passage; ways to improve and stabilize instream habitat in the river will be examined.

In order to determine the most effective way of restoring the aquatic habitat (i.e. reconnecting the river for migratory fish), it is necessary to quantify the habitat benefits that will be generated with each alternative. Ten alternatives have been developed which consist of various combinations of fish passage and habitat improvement measures. These alternatives are listed below:

1. No Action.

2. Dam removal at Wiley & Russell and Mill Street and fish ladder at Swimming Pool and Pumping Station.

3. Fish ladder at four dams.

4. Rock ramp at Wiley & Russell, removal of Mill Street and constructing fish ladders at Swimming Pool and Pumping Station

5. Fish ladder at Wiley & Russell, removal of Mill Street Dam and fish ladders at Swimming Pool and Pumping Station

6. Dam removal at Wiley & Russell and Mill Street and fish ladders at Swimming Pool and Pumping Station, in-stream work for habitat restoration downstream of Mill Street and at Leyden Woods.

7. Fish ladders at four dams, in-stream work for habitat restoration at Leyden Woods.

8. Rock ramp at Wiley & Russell, removal of Mill Street and fish ladders at Swimming Pool and Pumping Station, in-stream work for habitat restoration at Leyden Woods.

9. Fish ladder at Wiley & Russell, removal of Mill Street and fish ladders at Swimming Pool and Pumping Station, in-stream work for habitat restoration at Leyden Woods.

10. Rock ramp at Wiley & Russell, Fish ladders at Mill Street, Swimming Pool and Pumping Station Dams, in-stream work for Habitat Restoration at Leyden Woods.

The effects of these alternatives upon the aquatic habitat will be discussed below.

Existing Habitat

Three major ecosystem components will be evaluated in order to characterize and quantify the relative value of the habitat in the Green River between Wiley & Russell Dam (the most downstream) and the Pumping Station Dam (the most upstream). These are:

1) Lacustrine habitat, maintained by the existing impoundments behind Wiley & Russell and Mill Street, which support characteristic fisheries;

2) Riverine habitat, which currently exists upstream (and downstream from each of the dams and impoundments) and would improve under the various alternatives (including the restoration of an anadromous fish migration corridor). This habitat currently supports characteristic riverine fish species (although anadromous species are unable to pass through the existing river); and

3) Wetland habitat, which occurs primarily in one large section upstream from the Mill Street Dam, and is connected to it during times of high water.

Historical Fisheries

1. Anadromous/Riverine Fisheries

The Green River is believed to have historically supported runs of anadromous river herring (alewives and blueback herring), shad, sea lamprey, and Atlantic salmon, as well as the catadromous American eel. With the construction of the first dams downstream on the Connecticut and Deerfield Rivers, as well as the four dams on the Green River, these fish were no longer able to access their upstream spawning areas (and/or rearing areas for catadromous species), and consequently those populations were eliminated and/or reduced. In addition, the creation of impoundments upstream from these dams has locally changed these habitats from riverine to lacustrine, with resulting shifts in fish species composition.

The coldwater fish species currently inhabiting the Green River include brook trout, brown trout, and rainbow trout, which are seasonally stocked in various locations. In addition, largemouth bass, smallmouth bass, bluegill, yellow perch, pumpkinseed, red breasted sunfish, common shiner, and brown bullhead can be found in the impoundments behind the dams and in backwaters. Atlantic salmon fry are stocked in tributaries including Hinsdale Brook, which joins the Green River upstream from the Swimming Pool Dam, and downstream from the Pumping Station dam. In addition, anadromous alewives, blueback herring, and American shad, are found in the Deerfield River and the lower sections of the Green River below the Wiley & Russell Dam, however they are unable to pass upstream of the Wiley & Russell Dam. Other riverine species include fallfish, white sucker, tessellated darter, slimy sculpin, longnose dace, and blacknose dace (see Environmental Assessment for complete list of species). The provision of fish passage beyond the four dams on the Green River will allow these anadromous fish access to an additional 19.1 miles of riverine habitat, opening up a previously blocked migratory corridor with its associated spawning habitat. In addition, some of the resident species (e.g.. brown and brook trout, as well as smallmouth bass), have been observed utilizing fish ladders in other rivers, and are expected to do the same in the Green River if fish passage is provided.

2. Lacustrine/ Fisheries

The construction of the dams on the Green River has resulted in the creation of several acres of impounded (lacustrine) habitat upstream from each dam. These areas of quieter water generally can generally support more lacustrine fish species including largemouth bass, bluegill, yellow perch and bullhead, as opposed to the more riverine and/or coldwater species noted above. However, the artificially created lacustrine habitat within the impoundments is marginal, due to either the excessive siltation (Wiley & Russell, Mill Street, and Pumping Station) and/or lack of vegetation and other habitat structures (Swimming Pool and Wiley &Russell). In addition, there is an overall lack of shallow cover in these artificial impoundments, which is necessary reproductive habitat for many lacustrine fish species. Actual fisheries data from these areas is not available, however, direct observation has indicated clear water, with the bottom substrate consisting primarily of silt behind both Wiley & Russell and Mill Street dams, with no fish observed behind Wiley & Russell Dam. Although there were some smaller fish observed behind the Mill Street impoundment, large amounts of silt were present there as well, which could negatively affect water quality. At the Swimming Pool Dam, the substrate consisted of sand rather than silt, however minimal cover was present, and the artificial stone banks on the eastern side of the river precluded any kind of streambank habitat. In addition, sand from the beach side is continually washed downstream requiring yearly replacement. This further impacts the downstream habitat by covering the existing rock/cobble substrate characteristic of the streambed, which provides habitat for aquatic invertebrates. Of these impoundments, the one that appears to provide the best habitat is the area above the Pumping Station, which extends approximately 0.5 miles upstream and contains more areas of cover than the others. However, the bottom substrate in the vicinity of the dam is predominantly silt. Therefore, although these areas exist, their habitat value for lacustrine fish is not optimal. The lower dams will be affected by the proposed alternative/dam removal options however in that they would revert to riverine habitat if the dams were removed.

Wetland Habitat

Approximately 10 acres of wetlands are located upstream from the Mill Street Dam impoundment, primarily on the east side of the Green River, and appear to be hydraulically connected to it particularly during times of high water. These wetlands consist of an oxbow, as well as a small pond, locally referred to as "The Donut," which is connected to the oxbow by three culverts. The pond appears to be hydraulically connected to the Green River (i.e. the Mill Street impoundment) by a narrow discharge channel that enters the impoundment approximately 0.25 miles upstream from the Mill Street Dam. However, this channel has been empty during all of the site visits, with the standing water in the pond at a lower elevation than the bottom of the channel. These wetlands contain aquatic bed, emergent, forested and scrub-shrub cover types. In addition, there are areas of upland adjacent to and interspersed between the oxbow, pond and fringing areas along the margins of the impoundments.

The emergent wetland vegetation noted in the oxbow included cinnamon fern, tussock sedge, and scrub-shrub along the edges included alder and poplar. A large stand of reed canary grass dominated the inside of the bow. In the connected pond, areas of aquatic bed species included yellow water lily and water shield. Small swales were located along the banks of the Mill Street impoundment that were vegetated by sedges and stands of cattail. Stands of staghorn sumac were located along the upper bank areas upstream (outside of the wetland), and also along the upper wetland boundaries adjacent to the oxbow and pond. In the oxbow immediately adjacent to the Donut pond, the emergent vegetation along the edges was dominated by bur-reed (*Sparganuim* sp.). The forested area between the oxbow and the main impoundment had been highly modified, but consisted predominantly of white pine.

The diversity of cover types associated with these wetlands provide habitat for a variety of wildlife species including possible nesting habitat for waterfowl. In addition, the areas of forested upland in association with the wetlands provide habitat for avian and terrestrial wildlife species. Wetland birds that have been observed in this area include common merganser, great blue heron, mallard duck and snowy egret. Mammals observed in this area include red fox, white tailed deer, fisher, muskrat, beaver, and river otter. The continuity of these wetlands with the Mill Street impoundment allows waterfowl to nest in the backwater areas, while using the shallower open water associated with the wetlands for feeding (dabbling) and the deeper open water of the impoundment for resting and refuge. In addition, the combination of emergent, scrub-shrub and aquatic bed wetlands, forested uplands, and open water in close proximity to each other provides a diversified habitat, which contributes to the connectivity of the riparian corridor along the Green River.

There is a small shallow channel that connects the Donut with the Green River. The channel did not contain water during any of the site visits. However, on one occasion the substrate was wet indicating that there had previously been flow in the channel. Observation of the vegetation in the channel at that time indicated that the direction of the flow was from the Donut to the river (i.e. sedges and grasses were matted in the direction of the outflow). Based upon this information, it appears that during high rainfall events, the oxbow and The Donut discharge into the Green River.

In order to determine the hydraulic relationship between these wetlands and the Green River, staff gages were installed at five locations in the vicinity of the Mill Street impoundment and associated wetlands. These gages were placed in the legs of the oxbow, the Donut, and at two locations in the Green River, approximately 0.25 miles upstream from the dam (just downstream from the discharge channel in the Donut), and approximately 0.50 miles upstream from the Dam (i.e. upstream from the beginning of the wetland area). Measurements of the water elevations were collected four times through the spring and fall of 2002 (May through October). During each sampling event, the elevations of the standing water in both legs of the oxbow, and the Donut ranged from 0.95 to 1.70 feet higher than the elevation of the water measured at both locations in the Green River. Fluctuation of the water level in the Green River on those sampling events was 0.15 feet, while fluctuation of the water levels in the wetlands ranged between 0.20 and 0.35 feet.

These data suggest that the wetlands associated with the oxbow may be perched, containing standing water that was consistently at a higher elevation than that in the river. However, it is likely that during higher flood flows in the Green River, the impounded water backs up through the channel flooding the Donut as well as the oxbow. Therefore, there appears to be some influence of the Green River on the wetlands adjacent to them. If the Mill Street dam were removed, then this high water influence would only occur during extremely high flood events, and any resulting positive (and/or negative) effects of the river on the wetlands would be reduced. Positive effects from this could be the movement of fish from the Green River into the Donut pond, as well as the movement of fish out of these areas.

In addition, when considering the total drainage area of the wetlands above the Mill Street Dam, the storage capacity of the area, and the total expected water elevation drop of the river with the dam removed, the effects of the dam removal become more important. With the dam removed, the surface elevation of the river would drop to approximately 3 feet below the bottom of the Donut pond. Considering the existing sandy nature of the soils in the area and the proximity of the wetlands to the river, it appears that during the summer months, the Donut pond as well as the wetlands in the oxbow would drain to the existing river level. Therefore, the removal of the Mill St. impoundment may have a negative effect upon the associated wetlands upstream, with the potential loss of the Donut Pond as well as the wetlands in the oxbow. Although there is the potential that the existing springs which emerge from the base of the adjacent hillside will help to support these wetlands (in the absence of the river level), for the purpose of this study, it will be assumed that these wetlands will be significantly reduced, with a resulting negative effect on the associated resources. Therefore, the effects to these wetlands (with each alternative) will also be considered in this incremental analysis, with the lacustrine and riverine ecosystem components. It should be mentioned that the hydraulic effect of the impoundment on these wetlands is also artificial in that it did not historically influence them, but occurs as a result of the Mill Street Dam being in place.

Avian species that have been observed within the wetland and riparian areas of the Connecticut River Corridor include the pied-billed grebe, sedge wren, as well black duck and possibly the least bittern (Watershed Rarity Ranks for Species of Special Emphasis, in the Silvio O. Conte National Wildlife Refuge, Turner’s Falls MA). All of these species can be associated with vegetated wetland areas containing cattail marsh, and while they may not have been specifically observed in the immediate vicinity of Mill Street impoundment, could occupy these wetlands given the habitat types that occur there. In a similar emergent wetland in Milford Massachusetts, the least bittern as well as the pied billed Grebe have been observed, as well as mallard duck, which is generally associated with and utilizes the same habitat types as black duck (Veit and Petersen, 1993, and Laughlin and Kibbe, 1985). Generally, these species all use extensive cattail and sedge emergent marshlands adjacent to open water. Nests are built in the dense vegetative stands, and for some species, pied billed grebe), in areas on stands surrounded by and/or above areas of open water. Food items consist of wetland vegetation (i.e. seeds and/or plants) as well as aquatic invertebrates. It should be noted that the habitat requirements for all of these waterfowl, (as well as the other avian species noted above) depend upon the presence of open water (for foraging/dabbling) as well as the emergent wetland (for cover, and/or nesting). It will therefore be assumed, for this study that since similar habitat exists in the wetlands associated with the Mill Street impoundment (i.e. emergent and scrub-shrub vegetation adjacent to open water), these species can exist there. Food items that may support these species in the oxbow wetlands include Bur-reed (*Sparganuim* sp.), which as noted previously inhabits much of the edge habitat in the oxbow area. Bur-reed can provide excellent cover for nesting and breeding of various waterfowl species, and food for wood duck and king rail (Redington, 1994).

<u>Incremental Model</u>

1. Application

In order to compare the habitat benefits gained from providing fish passage beyond the four dams, it is necessary to compare the approximate habitat value of the Green River with the dams in place and the associated impoundments without fish passage (No Action Alternative) to the habitat value of the river with fish passage (with a project alternative). Providing fish passage beyond each of the four dams will improve the overall ecosystem, restoring it to a more historical condition by the reintroduction of anadromous fish and in the alternatives of dam removal, the restoration of historic riverine habitat. However, in some of the alternatives, the amount of emergent and or aquatic bed wetlands may be reduced with resulting negative effects to some of the wetland/waterfowl habitat, as well as a reduction/elimination of the existing lacustrine habitat and associated warmwater fish assemblage. In order to measure the benefits of the various restoration alternatives to the various habitat types, an evaluation of the quality and quantity of habitat suitable for various species (both aquatic and wetland) is necessary. The model presented below will be used to measure the overall changes in habitat that may occur incrementally with each of the various fish passage alternatives. This includes effects on wetlands (measured by waterfowl habitat), lacustrine habitat (measured by its ability to sustain target lacustrine fish species), and riverine habitat, (measured by its ability to sustain target anadromous fish species).

2. Model Design

a. Description

The U.S. Fish and Wildlife Service has developed Habitat Suitability Index Models for its Habitat Evaluation Procedures Methodology (HEP), which measure the suitability of a given habitat for one or more species. These models use habitat criteria (variables) that are necessary to support various species (and their life stages) in a given habitat. These habitat criteria (variables) are generally measurable in a given area of habitat and range in value from 0 (unsuitable) to 1 (optimal). By measuring each of these variables, summing and/or obtaining a geometric or arithmetic/weighted mean for them, an overall value of the habitat known as a Habitat Suitability Index (HI) can be obtained for a given species in a given habitat. When comparing various alternatives, the individual habitat variables can be estimated as to their expected change under each of the alternatives. The final HI obtained for each variable for a given species can then be multiplied by the acres of the restoration project to obtain another value, Habitat Units, which are a measure of the overall quality of the habitat (for that species) in the project area that will result from the restoration.

When evaluating an entire ecosystem, generally a group of species is selected which represents the various habitat types. The total Habitat Units calculated for each species are summed for each alternative and compared to determine which alternative provides the most effective restoration (based upon total habitat units gained by the project). When determining the habitat units for several species, it is possible for some of the same variables (which are essential to all species) to be measured and incorporated more than once (i.e. once for each target species). Therefore, a model, which can evaluate certain required habitat criteria common to more than one species, may be preferable to one that evaluates each individual species, and could provide a more general and/or alternative way of evaluating the overall quality and/or quantity of a habitat for a certain function.

The Habitat Suitability Index Models contain habitat suitability criteria necessary for all life stages of these species for a specific habitat. Many of the essential water quality (as well as physical habitat) criteria are common to several of the various freshwater lacustrine fish species as well riverine species. These include necessary water quality criteria (e.g.. pH, turbidity, temperature, dissolved oxygen) and physical/morphological habitat components (e.g.. forage, benthic invertebrates). By grouping specific life requisite criteria common to several target species into a single habitat component, a basic life requisite index for any body of water can be calculated. This can then be applied (by using a geometric mean) toward additional species-specific criteria necessary for a target species. For other non-fish species, a group of common wetland criteria can be developed as well, and then multiplied by target wetland species criteria (as well as the lacustrine and riverine components) output in the same manner.

For example, most warm water/lacustrine habitats in New England support a warm water fish assemblage, which includes species such as bluegill and pumpkinseed sunfish, yellow perch, brown bullhead, chain pickerel, black crappie, and largemouth bass. Generally, since these fish are typically found in lacustrine habitats, they have similar habitat requirements, which are common to more than one individual species. All of them (with the possible exception of brown bullhead) have similar dissolved oxygen requirements. Therefore, by measuring the range of dissolved oxygen levels in a specific habitat, the suitability of that habitat for a number of species that generally use this habitat and share similar dissolved oxygen requirements can be determined. Additional basic habitat requisites, such as forage habitat, pH, turbidity, that are common to a group of species can be measured, and then used as a general basic habitat model for a given type of habitat which supports a range of species. Species-specific habitat requirements can then be added, based upon target species, and weighted according to that species' importance to the ecosystem. The entire group of basic as well as species specific habitat requisites can then be either summed or multiplied (either to obtain a weighted and/or geometric mean) to obtain an overall habitat index which will rate the quality of the habitat to support a variety of species common to the area, as well as individual target species. The same approach can be applied to other ecosystem components in a given project, or other habitat types (such as wetlands as well as riverine) to obtain a total value ranging between 0 and 1, for each of them. The model presented below utilizes this method in order to obtain a measure of the habitat quality of the Green River Corridor through the Town Pumping Station Dam, and the impoundments behind Wiley & Russell and Mill Street Dams under various restoration alternatives.

3. Methods for Habitat Evaluation Model Used for the Green River

The differences between the model used below and the existing Habitat Suitability Index Models published by the Fish and Wildlife Service primarily have to do with the generalization and combination of several basic life requisites common to more than one species for the given habitat, with the addition of species specific criteria, to obtain a single overall suitability index for a given habitat type (or cover type), as opposed to using multiple species models and obtaining a suitability index for each species. However, the model below relies upon the Habitat Suitability Index Models to determine the general life requisite variables as well as the species variables. Other literature is also used, as well as professional judgment. Also, where many of the Habitat Suitability Index Models generally incorporate a geometric mean to reflect the necessity of each of the individual variables, or life requisites (and to express their independence), the model presented below uses both a geometric mean and weighted (arithmetic) mean to obtain the habitat index value (for each habitat type). This allows the essential life requisites to have the greatest effect on the overall output, in that if any one of them has an individual suitability index value of 0, the suitability index value of that entire habitat component becomes 0 regardless of any non-0 values of the other requisites (i.e. the habitat model is "life requisite" limited). However, if not all of the species specific criteria are suitable, and the general life requisites are suitable, then the total value of the habitat will still be above 0 (as long as there is at least one species specific criterion that is above 0), indicating that the habitat will support aquatic life at least temporarily, even though some of the requirements for a particular target species may be absent.

An individual Habitat Suitability Index (HI) will be obtained for each Habitat type in the vicinities of the Wiley & Russell and Mill Street Dams as well as in the upstream impoundments. The number of acres of the proposed project, or the number of acres of that particular habitat type in the project area that will be affected by each of the alternatives can then be multiplied by the HI for that particular habitat type to obtain a measure of Habitat Units (HU) for that particular alternative.

The three habitat types which will be evaluated for the Green River upstream from the Wiley & Russell and Mill Street Dams include riverine, which includes the acres of the Green River upstream from the limits of the impoundments and associated tributaries which would become accessible to anadromous fish if fish passage was provided; lacustrine, which includes the areas of the impoundments created by Wiley & Russell and Mill Street Dams (dam removal is not an alternative at swimming pool and Wiley & Russell, so their existing impoundments will not change with any of the alternatives); and wetland, which includes the fringing wetlands adjacent to the Wiley & Russell impoundment as well as those adjacent to the Mill Street impoundment which include the Donut and the oxbow. Those associated with the Wiley & Russell Dam are supported and maintained by the water level of the spillway, while the extensive wetlands upstream from the Mill Street Dam although also influenced by the water level in the impoundment, are additionally influenced by springs which are located at the base of the adjacent hillside. The Habitat Suitability Indices (HI) calculated for each of these types can be multiplied by the total area (acres) of that particular habitat type within the proposed project area that will become available with each of the alternatives, in order to obtain the total habitat units for that habitat type (i.e. riverine, wetland or lacustrine, etc.). The general formula is as follows:

$$\{[(GRf) * (TRf)]^{1/2}\}= HI(f);$$

$$\{[(GRr)*(TRr)]^{1/2}\} = HI(r); \text{ and,}$$

$$\{[(GRw)*(TRw))]^{1/2}\}=HI(w)$$

where

GRf = The geometric mean of each of the general lacustrine fisheries habitat requisites

TRf = The sum of the species specific habitat requisites (weighted mean) for specific lacustrine fish

GRr = The geometric mean of each of the general riverine/anadromous fisheries habitat requisites

TRr= The sum of the species specific habitat requisites (weighted mean) for specific riverine/anadromous fish

GRw = The geometric mean of each of the general wetland habitat requisites

TRw = The sum of each of the species specific habitat requisites (weighted mean) for specific wetland species i.e. waterfowl

HI(*h*) = Habitat Suitability Index for either riverine, lacustrine, or wetland habitat, ranging between 0 and 1.

(***h***) = Specific habitat type (either riverine, lacustrine or wetland)

The individual components are further defined as follows:

$$\mathbf{GRf} = \{\prod_{i=1}^{n} \mathbf{grf}_i\}^{1/n}$$

where
grf = each of the individual *general* essential habitat life requisites for lacustrine fish; and

$$\mathbf{TRf} = \{\sum_{i=1}^{N} \mathbf{trf}_i\}$$

where
trf = each of the *specific habitat requisites* for target lacustrine fish species (weighted according importance), and

$$\mathbf{GRr} = \{\prod_{i=1}^{n} \mathbf{grr}_i\}^{1/n}$$

where
grr = each of the individual *general* essential habitat life requisites for selected riverine species

and,

$$\mathbf{TRr} = \{\sum_{i=1}^{N} \mathbf{trr}_i\}$$

where
trr = each of the *specific* habitat requisites for target riverine/anadromous species (weighted according importance), and;

$$\mathbf{GRw} = \{\prod_{i=1}^{n} \mathbf{grw}_i\}^{1/n}$$

where
grw = each of the individual *general* essential habitat life requisites for selected wetland species
and,

$$\mathbf{TRw} = \{\textstyle\sum^{N}_{i=1} \mathbf{trw}_{i}\}$$

where

trw = each of the *specific* habitat requisites for target wetland species (weighted according importance).

Habitat Units are then obtained by the formula $\mathbf{HI}_{(h)} * \mathbf{A}_{(h)} = \mathbf{HU}_{(h)}$ **,** where

HI= Habitat Index obtained for either the lacustrine, riverine or wetland component from the above formulae

$_{(h)}$**=** The Specific habitat type (i.e. lacustrine, riverine or wetland/waterfowl)

A = Area of specific habitat type available for each proposed alternative within the project area

$\mathbf{HU}_{(h)}$ = Habitat Units for the specific habitat type

The total Habitat Units available for each habitat component for each alternative can then be summed according to the formula:

HU (**Total**)= $\{\sum^{N}_{i=1} \mathbf{HU}_{i}\}$

Where

HU (Total) = the total Habitat Units from all habitat types

Application of Generic Model to the Green River

In this incremental analysis, the overall habitat quality of the Green River ecosystem upstream from each of the impoundments (i.e. the impoundments and associated wetlands) will be evaluated under each of the proposed alternatives in order to determine the most effective restoration plan (i.e. the one which maximizes all of the various habitat benefits for lacustrine, riverine and wetlands). Comparison is made between the existing (lacustrine) fish habitat which has been formed by the construction of the dams and blocks the migration of anadromous fish, the wetland habitats created by the impoundments (particularly the one upstream from Mill Street Dam), that provide habitat for a variety of wildlife species, and the proposed restored migratory corridor (with or without the first two dams) which will allow the upstream (and downstream) passage of anadromous fish. In addition, the effects to the associated fringing wetlands habitat will be examined since these may be affected by the proposed alternatives.

Fisheries Habitat

1. Lacustrine Habitat/Species

Fisheries data from the Green River indicates the presence of several warmwater/lacustrine fish species. These include largemouth bass, smallmouth bass, bluegill, yellow perch, pumpkinseed, red-breasted sunfish, common shiner, and brown bullhead, and they are presumed to be associated with the impoundments behind the dams, as well as in slower moving areas of the river. Since several of the alternatives involve dam removal, which would eliminate their associated impoundments, benefits and/or effects of the various fish passage alternatives on this fish population will be specifically examined. The target species selected for this comparison is largemouth bass, since it currently exits in the Green River and is associated with the impoundments behind Wiley & Russell and Mill Street Dams, and the habitat appears to be physically suitable for them based upon the observable features of the impoundment. In addition, since these fish currently are present, it can be assumed that the basic habitat requirements for them are being met. In addition, it is assumed that the habitat requisites for this species will change in response to the various alternatives.

As noted in the previous section, in order to measure the changes in these requisites, a geometric mean was calculated by assigning individual values to each of a series of habitat components, which are necessary to generally support fish, and a weighted mean calculated to a series of habitat components essential to support target fish species (i.e. as noted for the lacustrine habitat component of the Green River, the target species is largemouth bass). These components (including the target species) were selected according to their importance in supporting fish and/or their function in the ecosystem (expected and existing). These were combined according to the general formula noted earlier. The HI calculated for each component was multiplied by the acres of that habitat type for each alternative to obtain the habitat units. These were totaled to calculate the total habitat units (for each type of habitat) for each of the alternatives.

Methods

Fisheries/Aquatic Habitat Component

General habitat criteria that are necessary to support lacustrine as well as riverine fish species that presently (and historically, since the construction of the dams) occupied the Green River and its impoundments were selected (GRf and GRr). These include the basic requisites for fisheries and/or aquatic life, which will change in response to dam removal and/or reduction of the elevations of the Wiley & Russell and Mill Street impoundments, and for which data sets are available. In addition, specific habitat requisites for a target lacustrine and riverine fish species were selected (TRf and TRr), which are also expected to change in response to dam removal and/or construction of a fish ladder. These target requisites were considered partially independently of the basic habitat requisites that are necessary to support any type of fishery in that they apply to an individual species, but also depend on the basic habitat requisites being met. This target fish grouping can consist of one or more target species, weighted according to their importance in the ecosystem and/or habitat restoration priority. As noted however, if any of the general requisites is unsuitable (value of 0), then the specific habitat requisites (for the target fish species) also become 0, due to their being multiplied by the index value obtained for the general requisites (which is a geometric mean of each of the individual variables necessary to support both lacustrine fish). This was done for each of the ecosystem components being examined for the Green River fish passage project (i.e. Lacustrine, Riverine, and Wetland/waterfowl). These requisites are listed below:

General Requisites for Lacustrine Fisheries Habitat (GRf)

1. Dissolved oxygen (grf_1)
2. Turbidity (grf_2)
3. Temperature (grf_3)
4. Benthic invertebrates (grf_4)
5. Cover (grf_5)
6. Forage (grf_6)

Species Specific Requisites for Warmwater Target Fish Species Habitat (TRf)

Target Species for the Green River is largemouth bass. Each of these requisites will be evaluated for the habitat as to its effect on this species

1. Littoral Habitat (trf_1)
2. Spawning substrate (trf_2)
3. Deepwater Habitat (trf_3)

General Requisites for Riverine Fisheries Habitat (GRr)

1. Dissolved oxygen (grr_1)
2. Turbidity (grr_2)
3. Temperature (grr_3)
4. Benthic invertebrates (grr_4)
5. Cover (grr_5)
6. Forage (grr_6)
7. Flow (grr_7)

Species Specific Requisites for Riverine/Anadromous Target Fish Species Habitat (TRr)

Target Species for the riverine habitat component of the Green River are brook trout, blueback herring, and Atlantic salmon. Each of the following requisites will be evaluated for each of the alternatives relative to its effect on each target fish species. For brook trout the requisites are:

1. Specific Cover (trr_1)
2. Percent Pool/Riffle (trr_2)
3. Spawning Habitat (trr_3)

For the anadromous species the requisites are:

1. Upstream passage ($trr_{4 \text{ and } 7}$)
2. Downstream passage ($trr_{5 \text{ and } 8}$)
3. Spawning Habitat ($trr_{6 \text{ and } 9}$)

(Discussion of how these variables will change specific to the various Green River fish passage alternatives will follow in the next section.)

A value was assigned to each of the requisites within each of the two functional groups of each habitat type (i.e. lacustrine, riverine or wetland) ranging from 0 to 1 depending on its existing condition with the dam in place and no fish passage, and its expected change for each of the fish passage alternatives. The actual value for each requisite was determined by considering specific data obtained from the Green River and comparing it to established criteria published in scientific literature as well as using direct observation of the affected habitat (using professional judgment). Many of the criteria that were used for both the general habitat requisites (GRf) and the specific habitat requisites (TRf) were found in the specific habitat suitability models for that species (HEP models).

These individual values assigned to each of the requisites were incorporated into the formula noted earlier for each of the habitat types to obtain the individual habitat suitability indices (HI). These Habitat Suitability Indices (HI) were then multiplied by the total acreage of that particular habitat type in the project to obtain the Habitat Units (HU) for that specific habitat type for each of the proposed fish passage alternatives for the Green River upstream from each of the four dams (Table 1). As noted there are ten alternatives proposed for this project that were previously listed on pages 1 and 2.

<u>Discussion of Values for Lacustrine Habitat</u>

General Requisites (GRf)

Dissolved Oxygen (grf_1) – Dissolved oxygen is required for all aquatic life. Water quality criteria for many freshwater fish species require a level of at least 5 mg/L, below which they begin to show signs of stress. Data collected by the U.S. Army Corps of Engineers during the summer of 2001 indicated dissolved oxygen levels ranging between 8.34 mg/L at the Mill Street impoundment, to 9.39 mg/L downstream from the covered bridge at the water supply dam. These levels are above the 5-mg/L criterion established for supporting aquatic life, and indicate near optimal water quality to support various lacustrine fish species. It should be noted that the although these dissolved oxygen levels were near optimal, the measurements from the Wiley & Russell and Mill Street impoundments were approximately 1 mg/L lower than those collected from the faster flowing sections near the discharges of the two upstream dams. This may be due to possible sediment or biological oxygen demand resulting from the sediments in the impoundments. However, in evaluating the suitability for existing fish species, as noted, these levels are near optimal, and not limiting. It should also be noted that the time of these measurements was during the daylight hours, and therefore not necessarily indicative of the lowest dissolved oxygen concentrations, which would occur in the early morning hours resulting from photosynthetic respiration (which occurs during the darkness).

Therefore, for the existing conditions this requisite was assigned a value of 0.80. With the dam removal alternative, it was assigned a value of 1.0 since the free flowing river will maximize aeration of the water, maintaining saturation. For the Denil Fish Ladder and Nature-Like Bypass Channel Alternatives, the dam and impoundment will remain, and there will be little or no effect on the existing dissolved oxygen level in the impoundment, so for these two alternatives this requisite was assigned values of 0.80 for each.

Turbidity (grf_2)-Excessive turbidity resulting from high levels of suspended solids is detrimental to maintaining healthy aquatic life. Generally, excessive turbidity can destroy benthic organisms preyed upon by many fish species at various life stages, by suffocation as well as covering over their sandier habitat. This can negatively affect the fisheries by eliminating the food supply of many fish larvae and adults. In addition, high levels of turbidity in the form of suspended solids can directly suffocate fish eggs and larvae, as well as irritate the gills of all life stages of most fish species. This can also lead to stress and/or suffocation. In addition, many fry and juvenile fish species feed primarily by sight, and elevated turbidities can significantly reduce visibility in the water column (El-Zarka 1959, from Krieger et al 1983). Largemouth bass are adversely affected by high levels of turbidity, which interfere with reproductive processes and reduce growth (Stuber et al, 1982). Black crappie prefer clear water and grow faster in areas of low turbidity (Edwards et al, 1982). Therefore, optimal lacustrine habitat would be that with low levels of turbidity.

As discussed in the Environmental Assessment, most of the Green River water contains clear water with low turbidity. However, direct observation of the substrate in Wiley & Russell and Mill Street impoundments indicated layers of extremely fine silt which was easily mobilized when disturbed. Although fish were observed in the Mill Street impoundment, the excessive amounts of silt, which are easily suspended, make this substrate less than optimal. Therefore, it is assumed that although the turbidity levels of the Green River in the vicinities of the Wiley & Russell and Mill Street impoundments are suitable for the survival of resident lacustrine fish species, they are less than optimal. They are assigned a value of 0.25 for the No Action Alternative (existing condition). For all of the dam removal alternatives, the substrate is expected to scour, reducing excessive silt, which has collected behind these dams. However, due to the silty nature of the soils along the bank of the Green River in the vicinity of the four dams, there is the potential for high turbidities during higher flow events. Therefore although these are expected to improve with dam removal, they are assigned values of 0.5 with the dam removal options, and not 1, due to the potential increased turbidity resulting from erosion. For the fish ladder alternatives since the impoundments will remain, these values were assigned the same as the no action alternatives. For the alternatives involving streambank and instream habitat restoration as well as dam removal, they were assigned values of 0.60 due to the stabilization of the riparian areas that have the potential to erode. For the options involving the removal of Mill Street only, they were assigned values of 0.38 and those with Mill Street only and the streambank stabilization they were assigned values of 0.45.

Temperature (grf_3)- The Green River has been classified by the Commonwealth of Massachusetts as a coldwater fishery. Coldwater fisheries can be defined as waters in which the maximum mean monthly temperature generally does not exceed 68°F (20°C) and, when other ecological factors are favorable (such as habitat), is capable of supporting a year-round population of cold-water stenothermal aquatic life such as trout (salmonidae). However, the four dams on the Green River have modified the historical habitat in the impoundments behind them from riverine, to slower moving lacustrine habitat. Generally, impounding of water increases its hydraulic residence time allowing it to warm during the spring and summer months, particularly in the surface layers. Although this can be detrimental to coldwater fish species, it can be beneficial to many warmwater fish species such as largemouth bass (particularly young of year) by increasing growth/metabolic rates (assuming that food is not limiting). However, data collected from the impoundments behind both Mill Street and Wiley & Russell did not indicate significant warming, compared to the main flow areas of the river, most likely due to the overall high flow in the Green River itself. Therefore, this requisite was assigned a value of 0.50 for the No Action Alternative. This requisite was not expected to change significantly for dam removal, so it was assigned the same value for all of the alternatives, including the fish ladders.

Benthic Invertebrates (grf_4)- Benthic invertebrates constitute a major food component of many fish species during one or more life stages. Therefore, they are important even to top predators, since many of the fishes that they prey upon (forage species) in turn prey upon smaller benthic invertebrates. Many lacustrine fish species feed on benthic invertebrates during at least one stage of their life. Yellow perch juveniles will dwell on the bottom of the littoral areas of lakes, and feed on amphipods, ostracods, and chironomid larvae; and the prey items of larger yellow perch include aquatic insects (Ward and Robinson 1974; Kelso and Ward 1977, from Krieger et al, 1983). Also largemouth bass fry and juveniles include insects in their diets (Emig, 1966; Zweiacker and Summerfelt 1974; Carlander 1977; from Stuber et al, 1982), which can include mayfly nymphs, chironomid larvae, caddisfly nymphs, as well as dragonfly and damselfly nymphs depending upon the relative size of the fish that is feeding (Scott and Crossman, 1973).

Although benthic invertebrate samples were not collected from the Wiley & Russell and Mill Street Dam impoundments, it appears that the highly silted bottom provides only marginal habitat for benthic invertebrates, which could be used as food items by resident lacustrine fish, particularly juveniles. The substrate in these impoundments consists of fine silt (as opposed to coarser sandy/mud). Numerous gas bubbles were observed rising from the sediments, presumed to be methane, indicating the presence of anaerobic conditions. Benthic organisms that can generally be found in sediments associated with slower moving waters (i.e. soft riverine substrata) include Tubicidae, Chironomidae, burrowing mayflies (Ephemiridae, Potamanthidae, Polymitarcidae), Prosobranchia, Unionidae, and Spaheriidae. If there is vegetation present, then it can support additional species (Hynes, 1970). Since most of this substrate is fine silt, with minimal vegetation, it is unlikely that diverse benthic communities exist in these impoundments but, more likely they are dominated by more pollution tolerant forms (chironomidae). The lack of large stands of rooted aquatic vegetation further limits the habitat. Therefore this requisite was assigned a value of 0.25 for the existing conditions (No Action Alternative).

For the dam removal option, this silt behind the dam would be flushed out, exposing the historic coarser sand/gravel substrate. This would provide habitat for those organisms more suited to flowing water, which are generally preyed upon by riverine species, although they can also be used by lacustrine fish species. Therefore for the alternative involving removal of both dams, this requisite was assigned a value of 0.4 since the improved substrate is expected to provide a more diverse benthic habitat, although not necessarily one typical of a lacustrine environment. For the single (Mill Street only) dam removal option it was assigned a value of 0.3 (to reflect the removal of only one dam), and for the fish ladder alternatives it was assigned the same value as the no action alternative (0.25) since the impoundments will remain in place.

Cover (grf_5)– This is a necessary component for all types of fish habitat. Fish need cover (or structure) in order to hide/holdover during times of inactivity, and predator species will hide while waiting for prey. Smaller fish and/or juveniles need cover in order to hide from larger predators and feed, and spawning nests for largemouth bass and many other lacustrine fishes are built where there is cover. In addition, most areas of cover also provide substrate for aquatic invertebrates necessary as food items. In lacustrine systems, cover consisting of aquatic vegetation, submerged logs and/or other debris and rocks are used as nursery habitat for juvenile fish, where they can hide and feed.

Minimal cover exists in the Wiley & Russell and Mill Street impoundments. As noted, much of the substrate is covered with extremely fine silt, and generally, with exception of the vegetated banks along the Mill Street Impoundment, the open water areas contain minimal submerged cover. The banks are relatively steep, and there are relatively few areas of vegetated shallows, which could be used as cover for both juvenile and adult lacustrine fish species. Therefore, this requisite was assigned a value of 0.35 for the No Action Alternative; a value of 0.25 for the Dam Removal Alternative since the habitat would revert to riverine, and be less suitable for lacustrine species; a value of 0.35 for the Denil Fish Ladder Alternatives (since the impoundment would remain); and a value of 0.30 for the removal of Mill Street only, since only one impoundment will be lost.

Forage (grf_6)- Larger predator fishes require forage species for food supply. Predator species in the Green River include largemouth bass as well as chain pickerel. With the existing conditions, forage may include young of year bluegills and pumpkinseed, young of year yellow perch, white sucker, and golden shiner, all of which have been found in the Green River, and occupy specific locations in either the impoundment or slower flowing areas of the river. In lacustrine habitats, golden shiner can be a primary forage species. Generally this species prefers clear quiet, weedy areas with extensive shallow areas (Scott and Crossman 1973).

Given the habitat and anecdotal information concerning the existing fishery, it is assumed that the existing forage base is sufficient to support the resident lacustrine fish in the impoundment. Therefore this requisite was assigned a value of 0.50 for the No Action Alternative. For the removal of both dams, it was assigned a value of 0.40 (relative to lacustrine habitat) since most of littoral areas of the impoundments utilized as nursery areas for forage species (i.e. golden shiner, bluegill, pumpkinseed) will be drained. For the Denil Fish Ladder and rock ramp option this requisite was assigned a value of 0.60, since with fish passage, additional forage fish will be allowed access to the impoundments (i.e. white sucker, which have been observed in the fish ladders at other rivers in the vicinity of the Green River, as well as the addition of up-migrating river herring through the impoundment), and the existing lacustrine habitat would not be drained. For the removal of Mill Street only this was assigned a value of 0.50 due to the loss of forage habitat there, but the increase in forage fish due to fish passage at Wiley & Russell below it.

Discussion of Target Lacustrine Fish Species Habitat Requisites (TRf)

Largemouth Bass

As noted previously, the target fish species selected to represent the lacustrine habitat in the Green River project area is largemouth bass. The three species-specific requisites that will be evaluated for this species are Littoral Habitat, Spawning Substrate, and Deepwater Habitat.

Littoral Habitat (trf_1)- Largemouth bass require littoral habitat (shallow areas) for spawning and nursery areas. Nests are constructed in water depths ranging from 0.15 meters to 7.5 meters, with the mean water depths ranging from 0.3- 0.9 meters (1-3 feet) (Stuber et al. 1982). Generally optimal largemouth bass habitat is characterized by lakes where at least 25% of the surface area of the lake and/or pond is shallow, i.e. less than 6 meters depth, but deep enough (3-15 meters) for the fish to successfully overwinter.

The impoundments behind the Wiley & Russell and Mill Street Dams with their relatively steeply sloping sides and general lack of associated emergent vegetation appear to provide minimal littoral areas for largemouth bass spawning and nursery. However, the presence of this species in the Green River indicates that successful spawning is occurring, and therefore suitable littoral habitat exists. Therefore, for the no action alternative, this requisite was assigned a value of 0.50. In the dam removal options, the impoundments will drain, reducing the existing littoral habitat. Therefore for these options it was assigned a value of 0.25. For the fish ladder and rock ramps the impoundments will remain intact, so this was assigned a value of 0.50 (the same as no action). For the removal of Mill Street only, this was assigned a value of 0.38 due to the loss of one of the impoundments.

Spawning Substrate (trf_2)-Optimal spawning substrate for largemouth bass is gravel, but other substrates, such as vegetation, roots, sand and mud are suitable. Silty and mucky bottoms are unsuitable (Numerous Citations, from Stuber et al, 1982). The impoundments behind the Wiley & Russell and Mill Street Dams, with the large amounts of fine silt appear to have minimal value as spawning substrate. However, as noted for the Littoral Habitat requisite, the existence of largemouth bass in the Green River indicates that there is suitable spawning substrate. Therefore for the no action alternative this was assigned a value of 0.40. For the dam removal option, this was assigned a value of 0.50, since the silt will be removed (although the available littoral areas may decrease, this requisite is measuring actual substrate quality). For the fish ladder/rock ramp options this was assigned values of 0.40 and for the single dam removal option this was assigned values of 0.45.

Deepwater Habitat (trf3)-Largemouth bass require depths of at least 9 feet to successfully overwinter (from Stuber et al, 1982). Maximum depths in the Wiley & Russell and Mill Street impoundments are approximately 8-9 feet. Therefore, they are less than optimal for largemouth bass overwintering. With the impoundments drained as would occur in the dam removal options, these become even shallower. Therefore this requisite was assigned a value of 0.40 for the existing conditions (no action) and alternatives that maintain the existing pool level (i.e. fish ladders). For the removal of both dams this was assigned a value of 0.20 since the impoundments will drain. For the removal of Mill Street only, this was assigned a value of 0.30.

Discussion of General Requisites for Riverine Fisheries Habitat (GRr)

Dissolved Oxygen (grr_1)- As noted above in the discussion on lacustrine habitat, dissolved oxygen concentrations in the Green River have generally met Class B Water Quality Standards, ranging between 8 and 9 mg/L (with the lower levels being measured in the impoundments). These levels are suitable for supporting most lacustrine fish species. They are also suitable for supporting many salmonid (i.e. coldwater) species. However, at warmer water temperatures (i.e. between 15^{o} C and 19^{o} C; as would be expected to occur in the Green River during the summer), optimal dissolved oxygen requirements for these fish (e.g. brook trout data) are greater, above 9 mg/L (Raliegh, 1982). Therefore this requisite was assigned a value of 0.75 with the No Action Alternative, and for those alternatives that maintain the existing levels of the Wiley & Russell and Mill Street impoundments. It was assigned a value of 1.0 for the two Dam

Removal alternatives because aeration will be maximized in the free flowing river. The options involving the removal of Mill Street Dam were assigned values of 0.88.

Turbidity (grr2) **–** Effects of high turbidities on riverine fish and invertebrates are similar to those noted previously for the lacustrine fish, and include gill irritation as well as reduced spawning efficiency (due to suffocation of eggs). In addition, brook trout (a coldwater/riverine species) are sight feeders, and therefore susceptible to even moderate increases in turbidities which reduce visibility in the water, negatively affecting feeding success. Also spawning success of brook trout is reduced as the amount of fine sediments increases due to the reduction of the interstitial oxygen concentrations (Raleigh, 1982). As noted in the previous lacustrine discussion, the turbidities are affected by streambank erosion as well as the re-suspension of accumulated silt from behind the impoundments (and other depositional areas of the Green River). These values will change depending upon the various alternatives, but will not differ significantly from the conditions described previously for the lacustrine component. Therefore, this requisite was assigned the same values as in the lacustrine component, which are 0.25 for the no action as well as those which do not involve removal of the existing impoundments; values of 0.5 for the dam removal options; 0.60 for the dam removal and instream stabilization. For the combination of alternatives, the values were 0.38 for options involving Mill Street only and no stabilization, and 0.45 for those involving Mill Street only and stabilization, and 0.30 for fish ladders and stabilization.

Temperature (grr3) As noted, impoundments created by the dams along the Green River can raise the water temperatures during summer months due to the increased hydraulic residence times and longer exposure to the atmosphere and solar radiation. While this may benefit warmwater fish, it does not benefit coldwater fish. Dam removal at Wiley & Russell and Mill Street would restore the historic flow and eliminate the impoundment induced warming, helping to maintain cooler water temperatures in those locations. Data collected from the impoundments behind Wiley & Russell and Mill Street during the summer of 2001 indicated relatively little warming occurring. Therefore relatively little change may occur if the dams were removed. However, slight increases in temperature (above the optimal) are more significant for coldwater/riverine species, than for lacustrine species. Therefore this requisite was assigned values of 0.50 for the existing conditions as well as for those alternatives that maintain the impoundments; 0.60 for the alternatives that involve the removal of both Wiley & Russell and Mill Street Dams, and 0.55 for those alternatives that involve the removal of Mill Street only.

Benthic Invertebrates (grr4)- As noted previously, the fine silty sediments noted in the Wiley & Russell and Mill Street impoundments do not provide optimal habitat for a diverse benthic community. Dam removal will restore historical flows through these areas causing them to scour exposing coarser gravel substrates more suited to a diverse benthic community. These would be available as food items for riverine fish species. Generally most of the sections of the Green River between the dams and the limits of the impoundments contain flowing water with scoured gravel and cobble substrate, which do provide habitat for a diverse benthic community. Preliminary field examination of the underside of several rocks revealed the presence of many caddisfly larvae, which are generally indicative of higher quality riverine conditions. In addition, the results of a recent macroinvertebrate survey of the Green River indicated that the macroinvertebrate communities in the river are not impacted relative to the regional reference site, located on the Cold River. All the sampled communities were largely composed of pollution-intolerant organisms (Cole, 2004). Therefore, this requisite was assigned a value of 0.75 for the existing conditions (no action alternative) as well as those which maintain the existing impoundments; 0.85 for the dam removal alternatives; 0.80 for the single Mill Street Dam removal option; and 0.83 for the rock ramp, since the rocks used for the construction of this would create additional benthic invertebrate habitat as well as potentially provide a migratory corridor for benthic invertebrates (FAO, 2002); and 0.90 for those options involving instream habitat stabilization, due to the anticipated reduction of the silt loads in these areas. For the combination of instream stabilization and dam removal these were assigned values of 0.85 and 0.84 for the rock ramp and fish ladder options respectively (which involved the instream stabilization).

Cover (grr5)- Generally, much of the riverine sections of the Green River (between the impoundments and the dams) contain cover in the form of larger boulders, downed trees, scoured pools and riffle areas. As noted earlier, only minimal cover exists in the impounded areas behind Wiley & Russell and Mill Street Dams. Most of the historic river bed in these areas, which would contain rock and boulder cover (and associated pools and riffle combinations) is covered by several feet of silt, and submerged under approximately 7 feet of water. If the impoundments were drained (i.e. Dam Removal option), these areas would become exposed and form rock riffle runs and pools with increased flows and higher levels of dissolved oxygen, which could be better utilized by resident fish. Therefore this requisite was assigned a value of 0.60 for the No Action Alternative. It was assigned a value of 0.80 for the removal of Wiley & Russell and Mill Street Dam removal alternative, since the historical riffle run sequence will be restored in these areas. For the fish ladder alternatives this was assigned values of 0.60 since the pools will remain. For the rock ramp options this was assigned higher values (0.73) due to the additional cover provided by the rock ramp structure, and for the total restoration alternatives (which include streambank improvements) this was assigned a value of 0.90 due to the optimization of the habitat in these areas. For the alternatives combining removal of Mill Street with some restoration, these were assigned values of 0.63, 0.78 and 0.65 for alternatives 7, 8 and 9 respectively.

Forage (grr6)-As noted in the lacustrine discussion, there is apparently sufficient habitat in the Green River (including the impoundments) to support forage species for the larger predators that inhabit the river. Generally, these forage fish would also be preyed upon by any larger riverine species (i.e. brook or brown or rainbow trout) that would be present in the Green River. With the Wiley & Russell and Mill Street Dams removed some of the littoral habitat necessary for the production of these lacustrine forage species would be removed, however the opening up of the historical riverine habitat (with its riffle/run/pool sequences) would allow population of the former impoundments by stream dwelling species, such as blacknose and longnose dace, creek chub, fallfish, as well as up-migrating and down migrating river herring. These species can provide additional forage for salmonids as well as other riverine species (smallmouth bass). In Canadian streams young and adult blacknose dace serve as food for large brook trout (Scott and Crossman 1973). Therefore, this requisite was assigned a value of 0.70 for the No Action Alternative, and a value of 0.85 for the Dam Removal Alternative (since the habitat will be improved for riverine species). For the Denil Fish Ladder alternatives it was assigned a value of 0.80, due to the reduced efficiency of fish ladders in passing fish compared to dam removal; a value of 0.83 for the Mill Street Dam removal option, and 0.83 for the rock ramp alternatives due to the higher efficiency of the rock ramps in passing fish. The instream options are not expected to affect the forage requisite, so there is no change in the values reflected for them.

Flow Velocity (grr7)-Water flow velocity is necessary for determining species composition in a river. Generally salmonid species require flowing water (i.e. upwelling) for redd construction and egg incubation, and various stream dwelling aquatic invertebrate species lack gills, and depend upon their contact with flowing water for oxygen exchange. Increasing flow to an impoundment will provide better aeration and reduce warming and possible thermal stratification. It may also eliminate stagnant areas with lower dissolved oxygen levels. This will generally increase the suitability of the fish habitat. Therefore, this requisite was assigned a value of 0.70 for the existing conditions (no action alternative), a value of 1.00 for the Wiley & Russell and Mill Street Dam removal alternatives; a 0.70 for the fish ladder alternatives (since the impoundments will be maintained); a value of 0.85 for the alternatives involving the removal of Mill Street Dam only. This requisite is not expected to be affected by any of the instream improvements.

Discussion of Target Riverine Fish Species Habitat Requisites (TRr)

As noted previously, the target fish species selected to represent the riverine habitat in the Green River project area are brook trout, blueback herring and Atlantic salmon. The species-specific requisites that will be evaluated for each of these species are: for brook trout: specific instream cover, percent pool and riffle ratio, and spawning habitat; and for blueback herring and Atlantic salmon they are upstream passage, downstream passage, and spawning habitat. Each of these fish species is assigned a value of 33.3% of the total riverine target fish species component **(TRr).**

Brook Trout

Specific Cover (trr1)-This is recognized as one of the basic and essential components of trout streams (Raleigh, 1982). Cover for trout includes areas of overhanging riparian vegetation, submerged vegetation, undercut banks, instream objects (stumps, logs, roots, and large rocks) rocky substrate, depth and water surface turbulence (Giger 1973, from Raleigh, 1982). Sections of the Green River between the four dams and impoundments are free flowing, passing through areas containing suitable brook trout habitat (as described above). However, the impoundments behind the dams, (specifically Wiley & Russell and Mill Street) lack sufficient cover for this species. With these dams removed, additional areas of rocky habitat will become available, improving the amount of available cover. Therefore, for the no action alternative as well as the fish ladder options, this requisite was assigned a value of 0.50. For the removal of both the Wiley & Russell and Mill Street Dams, this was assigned a value of 0.70. For the Mill Street Dam removal option this was assigned a value of 0.65, and for the Dam Removal with instream restoration this was assigned a value 0.95 since cover will be optimized in these sections. Slight increases were assigned for the rock ramp options due to the potential for the rocks to provide additional cover (i.e. 0.65 for option 4) and when these were combined with instream improvement (0.85 for option 8). It was assigned a value of 0.80 for option 9.

Percent Pools and Riffles (trr2)-Brook trout standing crops have been correlated with the amount of usable cover present, which is associated with velocities of </= 15 cm/sec and depths of >/= 15 cm deep. These conditions are generally associated more with pools than with riffle habitat, and are generally used by brook trout for resting and feeding. The best ratio is approximately 50% pools to 50% riffles (i.e. 1:1). Riffles provide habitat for a diverse benthic invertebrate community, utilized as food for brook trout and the 1:1 pool to riffle ratio is believed to provide an optimum mix of food producing and rearing areas (Numerous authors as Cited in Raleigh, 1982).

Although pool and riffle habitat is present in the Green River, the presence of the impoundments behind the four dams (specifically Wiley & Russell and Mill Street) reduces the pool and riffle ratios in these areas. Therefore this requisite was assigned a value of 0.60 for this option. For the removal of Wiley & Russell and Mill Street Dams, a value of 0.70 was assigned, since these impoundments will revert to historic riverine habitat more closely approximating ideal pool and riffle ratios. For the fish ladder options these were also assigned values of 0.60 since the impoundments will be maintained. For the alternatives involving rock ramp, these were assigned higher values due to the potential pool riffle habitat associated with the structure (0.65). For the options involving dam removal as well as instream restoration, these were assigned higher values due to the optimization of the habitat that will occur in these locations (0.95 and less for various combinations of dam removal and instream work).

Spawning Habitat (trr3) – Optimal spawning habitat for brook trout consists of upwelling water with gravel ranging from 3-8 cm in diameter containing less than or equal to 5% fines. The silt-covered substrate present in the impoundments behind the Wiley & Russell and Mill Street are not suitable brook trout spawning habitat. However, potential brook trout spawning habitat (as described above) has been observed in sections of the Green River between the impoundments. One area in particular is located in the vicinity of the Leyden Woods apartments, where a large gravel bar had formed near a bend in the river, from which there was an emergent spring. Other similar gravel bars are located along the Green River within the study area. These would also provide potential brook trout spawning habitat. Areas of the impoundment reduce the amounts of available spawning habitat while the instream restoration of sections of the river will maximize spawning habitat. Therefore this requisite was assigned a value of 0.60 for the existing conditions (no action), and those alternatives that maintain the pools behind Wiley & Russell and Mill Street Dams (alternative3); 0.80 for the alternatives where these two dams are removed; a value of 0.70 for removal of only Mill Street, and a value of 0.90 for those alternatives involving instream restoration and dam removal. The alternatives that involve combinations of single dam removal and habitat improvements (alternative 8) were assigned values 0.85; and the alternative of no dam removal and habitat improvements were assigned values of 0.75.

<u>Blueback Herring</u>

Upstream Passage (trr1)-With the existing conditions, there is no upstream passage for this species beyond the any of the four dams. Therefore this requisite was assigned a value of 0 for the No Action Alternative. With removal of Wiley & Russell and Mill Street Dams, there will be un-impeded fish passage to the Swimming Pool Dam and then passed the Pumping Station dam, since these are also proposed to have fish ladders allowing these fish access to approximately 19.1 (as calculated for this incremental analysis) additional river miles on the Green River. Therefore it was assigned a value 0.90 for the dam removal option (not 1 due to the inefficiencies of the fish ladders at Swimming Pool and Pumping station dams). For the fish ladder alternatives it was assigned a value of 0.70 (Alternative 2); and for the combination of rock ramp and Mill Street Removal, a value of 0.85 due to the increase in efficiency of these passage facilities compared to ladders (Laine, 2001; FAO, 2002; and Bunt et al, 1999). For the single dam removal options (Mill Street) this was assigned a value of 0.80. This requisite will not be affected by any instream work. It should be mentioned that the passage efficiencies of the fish ladders used in this incremental analysis are estimates based upon their overall ability to pass a number of target species, and the differences between the various passage alternatives are relative and used for comparison between the various alternatives.

Downstream Passage (trr2)- Currently blueback herring are not migrating through the Green River above the Wiley & Russell Dam. Therefore there is no upstream or downstream passage of them beyond the dams. However, since habitat exists upstream from these dams, there is the potential for downstream passage if these fish were stocked. However, passing fish over dam spillways that have not been modified for downstream passage, is not effective, and can cause injury to these fish by contact with the concrete aprons, etc. Also low flow over these dams further reduces the success of downstream passage over them. Therefore, this requisite was assigned a value of 0.25 for the No Action Alternative.

With the Wiley & Russell and Mill Street Dam Removal Alternative with upstream fish ladders, the restored river channel will optimize downstream passage so this requisite was assigned a value of 0.90 (not 1 since there will still be fish ladders and modified downstream passage at the two upper dams). For the Mill Street option these are assigned a value of 0.85 and for the four fish ladder option a value of 0.80. For the rock ramp options, it was assigned a value of 0.82 due to the increased efficiency of this type of structure.

Spawning Habitat (trr3)-Blueback herring spawn in swift –flowing, deeper stretches of rivers and streams with associated hard substrate, as well as slower flowing tributaries and flooded low –lying areas adjacent to main streams with soft substrates and detritus (numerous citations from Pardue, 1983). Currently they spawn in areas of the Deerfield River, as well as the Falls River, which is similar in size and flow to the Green River. Suitable spawning habitat exists for this species upstream from the Water Supply Dam, as well as in other locations of the River (between the dams as well as in the impoundments). Therefore this requisite was assigned a value of 0.5 for the no action alternative, and those which maintain the pool elevations; a value of 0.80 for the Dam removal alternative (since hard substrate habitat will be opened by the removal of these dams, however, there may be a reduction in the potential slower flowing habitat provided by the impoundments themselves); and a value of 0.65 for the single Mill Street Dam removal option. The instream habitat changes are not expected to significantly affect the spawning habitat for this species. Therefore this was assigned values of 0.65 and 0.50 for the alternatives that involve single dam removal and fish ladders respectively.

Atlantic Salmon- This species is currently the subject of an ongoing restoration effort. As noted previously fry are stocked in the Green River as well as in several tributaries.

Upstream Passage (trr7)-This requisite was assigned the same values as for Blue back herring alternatives. They are: 0.00; 0.9, 0.75, 0.85, 0.80, 0.90, 0.75, 0.85, and 0.80 for alternatives 1-9 respectively.

Downstream Passage (trr8)- This was also assigned the same values as for the other two anadromous species listed above, and for the same reasons.

Spawning Habitat (trr9)-As noted previously, it is presumed that Atlantic salmon historically spawned in the Green River and its tributaries. Therefore historic spawning habitat exists in the watershed. Atlantic salmon require cold clear streams with small cobbles/gravel bottoms for construction of spawning redds. Suitable spawning habitat exists in tributaries to the Green River as well as in areas of the River itself. This requisite was therefore assigned a value of 0.60 for the No Action Alternative; a value of 0.90 for the removal of both Wiley & Russell and Mill Street Dams which may create additional spawning habitat in these sections; a value of 0.60 for the fish ladder alternatives since the pools will remain intact, and a value of 0.95 for the Dam removal and instream restoration alternatives since this may optimize Atlantic salmon spawning habitat. The combination alternative involving the Mill Street Dam Removal and instream improvements were assigned values of 0.65 and 0.80 for the alternatives 7-10 respectively.

Wetland Habitat Requisites

General Habitat Requisites for Wetland Avian Species/Waterfowl

As discussed previously, areas of fringing wetlands, which includes emergent wetlands as well as forested uplands, border the Mill Street impoundment. These areas could potentially provide habitat for a number of avian species, which include mallard duck (and presumably black duck). In addition although not specifically observed in the Mill Street area, other avian species such as pied billed grebe, common moorhen and least bittern inhabit the Connecticut River corridor, which is less than one mile from the Green River in the vicinity of the Mill Street Dam. The set of general habitat requisites (**GRw**) necessary for all of these species include:

1) **The percent of emergent and scrub shrub wetland vegetation containing cattail and sedges adjacent to open water (grw$_1$).** This is defined by the actual area of this type of habitat and its proximity to an area of open water, based upon the assumption that the cover for refuge and nesting habitat is as important as the open water is for feeding habitat. This is also a measure of the location of the wetland in relation to the body of water. Assumptions are that a long narrow edge of this type of habitat is less suitable than a circular or rectangular tract of habitat located near the body of water with its edge extending in the water, or a long narrow strip of water adjacent to a larger area of emergent cattail marsh. Therefore those areas with long narrow edges would be less optimal than those that contain approximately equally sized areas. However, it also may be beneficial for these areas of the emergent cattail habitat to be divided into two or more larger areas surrounded by open water (i.e. islands), since some species nest in smaller areas of cattail marsh surrounded by open water i.e. Pied Billed Grebe. The assumption is that the optimum ratio or percentage would be 50:50.

2) **The percent of open water < 3 feet deep (grw$_2$).** This is utilized by dabbling ducks as well as other avian wetland species. This is necessary for dabbling (feeding), in order for the various waterfowl noted above to reach the bottom, which contains food items. .

3) **Ratio of open water to emergent vegetation (grw$_3$)** (50:50 is optimal) (Waterfowl Management Handbook, 1992; Vermont Agency of Natural Resources, 1999). This measures the actual amounts of emergent vegetation in the water itself (i.e. the shallow and/or deeper areas inhabited by aquatic vegetation). It is the measure of the area of the open water itself occupied by emergent vegetation, as compared to the un-vegetated open water. This is generally used by most waterfowl species for most life stages, i.e. nesting and refuge habitat would be in the emergent vegetation, and feeding habitat would be in or near the open water, or edge areas.

These three variables comprise the general wetland habitat requisites for the Green River upstream from the Mill Street Dam as noted in the general formula on pages 5 and 6 (**GRw**). They will be discussed in further detail below, and also evaluated as to their degree of change with each of the alternatives to obtain individual values (**grw**).

Specific Habitat Requisites for Target Species (TRw) -Black Duck (*Anas rubripes*).

The specific Habitat Requisites for this species include

1) **The density of the rooted (including emergent) vegetation present in the open water areas (trw_1)**. Assume that a density of 50% is optimal. Denser stands can interfere with swimming, feeding, and can cause entanglement.

2) **Percent of backwater supporting insect larvae (trw_2)** (i.e. mosquitoes) and other invertebrates for feeding of young (assume that 50:50 is optimal). It would be measured by the amount of small shallow pools located or interspersed with the emergent wetland vegetation. Newly hatched black duck young (as well as ducklings of most other species) feed on mosquito larvae, and other invertebrates (Environment Canada, 1980). In addition, pre-nesting adults require additional protein in the form of aquatic invertebrates found in shallow diverse wetland communities.

3) **Percent of nesting habitat (i.e. scrub shrub/emergent vegetation within 1 mile of water) (trw_3)**. This would generally measure other types of habitat present (i.e. scrub shrub) wetland within one mile from the open water, in addition to the existing cattail/sedge habitat. This species can generally nest in sedge, scrub/shrub, or wooded habitats. However in Maine this species preferred sedge shrub marshland when available (Kibbe and Laughlin, 1985). These areas need to be within a reasonable distance from the water to minimize mortality of young during their migration from the nesting areas.

Each of these specific habitat requisites (trw) for the target species (i.e. black duck) will be assigned a value for each alternative and incorporated into the general formula noted above, in order to obtain the overall index value for the fish and waterfowl habitat in the Green River.

Discussion of General Habitat Requisites for Wetland Avian Species/Waterfowl

1. **Percent of Cattail Marsh and/or scrub shrub vegetation adjacent to open water:**

As noted, the habitat behind the Mill Street impoundment contains some cattail marsh however it is predominated by other species (i.e. alder, poplar, sedge, burreed). This may be partially maintained by the impoundment, and could provide nesting habitat for Mallard and/or black duck as well as other avian wetland/waterfowl species.

Many waterfowl species (i.e. black duck and/or mallard duck) utilize emergent cattail marsh habitat for cover and nesting. American Black Duck (*Anas rubripes*) habitat includes open marshes, to densely wooded swamps (Veit and Petersen, 1993); such as beaver ponds, glacial kettles, surrounded by bog mats, along creeks, and rivers, on lakes in swamps as well as extensive sedge or cattail marshland. However in Maine, this species preferred sedge-shrub marshland when available (Kibbe and Laughlin, 1985). It is assumed that the habitat requirements for mallard duck would be similar, since this species is often found associated with black duck, and is believed to interbreed with it.

2. The percent of open water less than 3 feet deep. Shallow water less than 3 feet deep is used by avian wetland and waterfowl species. Dabbling ducks including black duck require areas of open water less than 3 feet deep in order to forage (Fish and Wildlife Service, Habitat Suitability Index Model for Black Duck). In addition the Common moorhen, which occurs in nests in areas of water less than 3 feet deep. (Common Moorhen fact sheet, Commonwealth of Massachusetts).

3. Ratio of open water to emergent vegetation. In addition to the amount of cattail and sedge wetland noted in the first variable, the amount of the open water (either shallow or deep) occupied by emergent vegetation is important. Wetlands most attractive to dabbling ducks contain about a 50:50 ratio of open water to emergent vegetation. Patches of emergent plants, sparse enough to allow a duck to swim through are more attractive than large blocks of thick, unbroken vegetation (Waterfowl Management Handbook, 1992; Vermont Pond Construction Guidelines, 1999).

Application of Variables to the Green River, Upstream from the Mill Street Dam. These requisites with their values and functional grouping are discussed below. Habitat indices were calculated for the nine alternatives noted previously.

<u>Wetland General Requisites (GRw).</u>

Emergent Vegetation/Scrub Shrub (grw1) - Upstream from the Mill Street impoundment, there several small stands of cattail marsh, however as noted the predominant cover types consist mainly sedges, alder and poplar. Therefore this was assumed to be less than optimal for this requisite, and assigned a value of 0.70 for the No action alternative. For the alternatives that involve the Mill Street Dam removal this was assigned a value of 0.15 due to the expected loss of the water levels. It was not assigned a value of 0, due to the influence of the existing drainage from the hillside, which may partially support some of these wetlands.

Percent Open Water Less than 3 feet Deep (grw2)- Upstream from the Mill Street Dam sufficient open water is present in the Donut pond. Therefore this requisite was assigned a value of 0.90 for the no action alternative. For the alternatives involving the removal of Mill Street Dam this was assigned a value of 0.25, due to the expected loss of the Donut pond. However the river itself may provide some dabbling habitat, therefore, it was not assigned a value of 0.

Percent Vegetated Open Water (grw3)- For the Green River upstream from Mill Street Dam, the areas of the Donut Pond appear to be have a suitable ratio for this requisite. It was therefore assigned a value of 0.90 for the no action alternative, and a ratio of 0.15 for the alternatives involving the removal of Mill Street Dam, due to the loss of the Donut Pond. It was not assigned a value of 0 due to the habitat potential of the river itself.

Specific Habitat Requisites (Black Duck)

The values assigned to these requisites are discussed below for the various alternatives.

The density of the rooted (including emergent) vegetation present in the open water areas (trw_1)- This was assumed near optimal for the existing condition and was assigned a value of 0.90. For the Dam Removal Alternative, this was assigned a value of 0.30 for since most of the impoundment will drain. However, some of the larger pools left in the river may provide an area for rooted vegetation to establish. Since the deep area of the river (noted in the lacustrine section) may still provide some deeper riverine pools.

Percent of backwater supporting insect larvae (trw_2)- The pools and wetlands upstream from the Mill Street Dams appear to contain sufficient areas of backwater. Therefore this was assigned a value of 0.90 for the alternatives that maintain the existing water levels that maintain the wetland. This requisite was assigned a value of 0.25 for the Dam Removal Alternative, since most of the backwater is contained in the adjacent wetlands, which will drain with Dam Removal.

Percent of nesting habitat (i.e. scrub shrub/emergent vegetation within 1 mile of water) (trw_3). **-**This was assigned a value of 0.90 for the No Action Alternative, and 0.75 for the Dam Removal Alternative since it is presumed that there will still be some areas of vegetated scrub shrub suitable for nesting within 1 mile of the impoundment, even with the impoundment gone.

Calculation of Habitat Units

Habitat Units for each of the Green River fish passage alternatives were calculated according to the formula noted above, where the Indices obtained for the lacustrine (i.e. fisheries) habitat, riverine (i.e. anadromous fish) habitat and wetland (i.e. waterfowl) habitat were multiplied by the total acres of the respective habitat types that will become available with each alternative. These calculations of individual Habitat Indices (HI) are presented in the attached spreadsheet with the respective Habitat Units (HU) (See Attachment 1). The acreages used to obtain the habitat units are presented below along with the methods used for calculating them as well as the methods used to obtain the Habitat Units for each of the respective alternatives.

Alternative 1- No Action

Lacustrine Habitat-The Wiley & Russell and Mill Street Dams create impoundments that are approximately 4.48 and 6.62 acres respectively. This was estimated from aerial photography using the Arcview GIS measuring tool to determine the length of the impoundment and taking an average width. Therefore the total amount of lacustrine habitat was estimated as 11.10 acres. This was multiplied by the lacustrine HI obtained for this alternative

Riverine Habitat-The total river miles for the study area is approximately 19.1 which includes all of the dams. Using mean widths of the river measured along the entire study course, the total acreage for the river was calculated as 156.76 acres. This includes the acreages of the Wiley & Russell impoundments as well, since these will remain part of the river in the fish ladder alternatives. This was multiplied by the Riverine HI obtained for that alternative.

Wetland/Waterfowl Habitat-There are approximately 15 acres of wetlands interspersed with uplands adjacent to the Mill Street impoundment, apparently influenced by the existing water level (which is the spillway elevation) (See Attachment 1). In addition, it is assumed that any waterfowl that occupy these wetlands also utilize the open water of the Mill Street impoundment, which as noted above is approximately 6.62 acres. Therefore a total of 21.47 acres of wetland/waterfowl habitat exists in the vicinity of Mill Street Dam. This acreage also includes the fringing wetlands across the river. This was multiplied by the wetland/waterfowl HI for that alternative.

Alternative 2-Dam Removal of Wiley & Russell and Mill Street Dams, Fish Ladders at Swimming Pool and Pumping Station

Lacustrine Habitat-In this alternative, the impoundments behind Wiley & Russell and Mill Street would drain, (which could potentially influence the associate wetlands behind Mill Street Dam). The habitat would revert to the historical riverine habitat upstream from the two removed dams. The loss of the impoundment would eliminate approximately 2.24 acres of open water habitat at Wiley & Russell, and 3.74 acres of open water at Mill Street. These areas would be replaced by free flowing river, for a total reduction of approximately 6 acres for a total 5.12 acres of lacustrine habitat for this option. This was multiplied by the Lacustrine HI obtained for that Alternative

Riverine Habitat- The loss of the 6 acres from the impoundments noted above also reduces the riverine acres by the same amount since they were counted previously as part of the riverine acres as well as the lacustrine acres. Therefore, the total acres of riverine habitat that will be available under the two dam removal alternative are approximately 150.77 acres. This was multiplied by the Riverine Habitat Index for obtained for this alternative

Wetland/Waterfowl Habitat-With Dam Removal, the 11.1 acres of wetland habitat adjacent to the Mill Street impoundment and influenced by it would be reduced by the impoundment loss, a reduction of approximately 3.74 acres of open water. Therefore the Wetland/Waterfowl habitat acres would drop from 21.47 to 17.73 acres. This was multiplied by the Wetland HI obtained for this alternative.

<u>Altnerative 3-Fish Ladders at Four Dams</u>

Lacustrine Habitat-Since the impoundment will remain in place in this alternative, there will be 11.10 acres of lacustrine habitat, the same as for the No Action Alternative. This was multiplied by the Lacustrine HI obtained for that alternative.

Riverine Habitat-For this alternative, the impoundment upstream from the dam as well as the wetlands will remain intact. Therefore the acres of water surface will remain at 156.76 (as in the No Action Alternative). This was multiplied by the Riverine HI for this alternative.

Wetlands/Waterfowl-Since the impoundment will remain in this alternative, the 21.47 acres of associated wetland/waterfowl habitat influenced by it will remain unchanged. This was multiplied by the Wetlands HI for this alternative

<u>Alternative 4- Rock Ram at Wiley & Russell and the Removal of Mill Street Dam, with Fish Ladders at Swimming Pool and Pumping Station Dam</u>

Lacustrine Habitat-The lacustrine habitat will remain at 4.48 acres for the Wiley & Russell Dam, but will be reduced to 2.88 acres at the Mill Street Dam due to the loss of the impoundment there, for a total of 7.36 acres of lacustrine habitat for this alternative. This was multiplied by the Lacustrine HI for that alternative

Riverine Habitat- The Riverine Habitat will be reduced by the loss of the Mill Street Impoundment, from 156.76 acres to 153.01 acres. This was multiplied by the Riverine HI for that alternative.

Waterfowl/Wetland Habitat- The wetland/waterfowl habitat will be reduced by the loss of the associated open water at Mill Street Dam, decreasing from 21.47 acres to 17.73 acres. This was multiplied by the Riverine HI for that alternative.

Alternative 5 – Fish Ladder at Wiley and Russell, Removal of Mill Street and Fish Ladder at Swimming Pool and Pumping Station

Lacustrine Habitat- The lacustrine habitat will be the same as those for alternative 4, for since the Wiley & Russell will remain and the Mill Street will be removed, for a total of 7.36 acres. This was multiplied by the Lacustrine HI for that alternative.

Riverine Habitat –As with alternative 4, the riverine habitat will be reduced by the loss of the Mill Street Impoundment from 156.76 acres to 153.01 acres. This was multiplied by the Riverine HI for this alternative.

Wetland/Waterfowl Habitat- The wetland/waterfowl habitat will also be the same as in Alternative 4, with a loss due to the removal of the Mill Street Impoundment for a total of 17.73 acres. This was multiplied by the Wetlands/Waterfowl HI for that alternative

Alternative 6-Dam Removal at Wiley & Russell and Mill Street and Fish Ladder at Swimming Pool and Pumping Station Dams, with In-Stream Work for Habitat Restoration d/s of Mill Street and at Leyden Woods

Lacustrine Habitat – Due to the impoundment loss at both Wiley & Russell and Mill Street, total lacustrine acreage will be reduced from a total of approximately 11 acres to 5.12. This was multiplied by the Lacustrine HI obtained for this alternative obtain Habitat Units.

Riverine Habitat- This will also be reduced by approximately 6 acres from the loss of the impoundments, decreasing from approximately 156.76 to 150.77. However, approximately 3.75 acres of this will be restored (i.e. 1.5 acres at Leyden Woods and 2.24 acres above Mill Street) which is subtracted from the 150.77 and multiplied out separately for a total of 147.03 riverine acres for this alternative plus the 3.75 acres of restored riverine instream habitat. Therefore the 147.03 acres of Riverine without instream work was multiplied by the riverine HI obtained from alternative 2, and the remaining 3.75 acres was multiplied by the Riverine HI obtained for this alternative.

Wetlands Waterfowl Habitat- This will be reduced due to the loss of the Mill Street Impoundment, decreasing from 21.47 acres, to 17.73 acres. This was multiplied by the Riverine HI obtained for this alternative.

Alternative 7 - Fish Ladder at Four Dams, In-stream Work for Habitat Restoration at Leyden Woods

Lacustrine Habitat- Due to both the Wiley & Russell and Mill Street impoundments remaining in place, the total lacustrine acreage will remain at 11.10 acres. This was multiplied by the lacustrine HI obtained for this alternative.

Riverine Habitat - This will remain at 156.76 with 1.5 acres being restored at Leyden Woods. Therefore 155.26 acres will be multiplied out separately from the 1.5 acres. Therefore, 155.26 acres was multiplied by the HI obtained for Alternative 3, and 1.5 acres was multiplied by the HI obtained for Alternative 7.

Wetlands Waterfowl Habitat- This will remain at 11.10 acres due to the Wiley & Russell and Mill Street impoundments remaining. This was multiplied by the HI obtained for this alternative.

Alternative 8- Rock Ramp at Wiley & Russell, remove Mill Street and Fish Ladder at Swimming Pool and Pumping Station, In-stream work for Habitat Restoration at Leyden Woods

Lacustrine Habitat- This will be reduced by the loss of the Mill Street Dam, decreasing from 11.1 acres to 7.36 acres. This was multiplied by the lacustrine HI obtained for this alternative

Riverine Habitat – This will be reduced by the loss of the Mill Street Impoundment from 156 to 153, with an additional decrease of 1.5 for the Leyden Woods section which is multiplied separately for a total of 151.51. Therefore, 151.51 acres was multiplied by the Riverine HI obtained for alternative 4, and 1.5 acres was multiplied by the riverine HI obtained for alternative 8 (this alternative).

Wetlands/Waterfowl Habitat – This will be reduced to 17.73 acres due to the loss of the Mill Street impoundment. This was multiplied by the Wetlands/waterfowl HI obtained for this alternative.

Alternative 9 – Fish Ladder at Wiley & Russell, Remove Mill Street and Fish Ladder at Swimming Pond And Pumping Station, In-Stream work for Habitat Restoration at Leyden Woods

Lacustrine Habitat – This will be the same as in alternative 8, due to the loss of the Mill Street, for a total of 7.36 acres. This acreage was multiplied by the Lacustrine HI obtained for this alternative.

Riverine Habitat - This will also be the same as for alternative 8, for a total of 151.51 separated from the amount of streambank restoration of 1.5 acres. The 151.51 acres was multiplied by the riverine HI obtained for alternative 5, and the 1.5 acres of streambank restoration was multiplied by the HI obtained for alternative 9.

Wetland/Waterfowl - This will be reduced by the amount of the loss of the Mill Street Impoundment to 17.73 acres. This was multiplied by the HI obtained for this alternative.

Habitat Units

Using the acreages calculated above for each habitat type, habitat units were calculated by multiplying them by the respective Habitat Suitability Index (HI) obtained for each alternative. As noted above, various alternatives involve the reduction of overall acreages, and the separation of acreages in order to represent habitat improvements that affect specific areas.

Alternative 1, No Action

Lacustrine HU's = 4.65.
Riverine HU's = 71.91
Wetland/Waterfowl HU's = 18.52

Total Habitat Units =95.08

Alternative 2, Removal of 2 Dams with Fish Ladders at 2 Dams

Lacustrine HU's = 1.96.
Riverine HU's = 121.38
Wetland/Waterfowl HU's = 4.92

Total Habitat Units = 128.26

Alternative 3, Fish Ladders at all 4 Dams

Lacustrine HU's = 4.72
Riverine HU's = 97.08
Wetland/Waterfowl HU's = 18.52

Total Habitat Units = 120.32

<u>Alternative 4, Rock Ramp at Wiley & Russell, Removal of Mill St and Fish ladders</u>

Lacustrine HU's = 3.01
Riverine HU's = 111.02
Wetland/Waterfowl HU's = 4.92

Total Habitat Units = 118.94

<u>Alternative 5 – Fish Ladder at Wiley & Russell, Removal of Mill St. and Fish Ladders at Swimming Pool and Pumping Station</u>

Lacustrine HU's = 3.01
Riverine HU's = 108.23
Wetland/Waterfowl HU's =4.92

Total Habitat Units =116.16

<u>Alternative 6- Dam Removal at Wiley & Russell and Mill Street, Fish Ladders at 2 upstream Dams, and in-stream Habitat improvements at Wiley & Russell and Leyden Woods</u>

Lacustrine HU's = 1.99
Riverine HU's = 121.59
Wetland/Waterfowl HU's =4.92

Total Habitat Units =128.50

<u>Alternative7 –Fish Ladder at all Dams. In-stream work for Habitat Restoration at Leyden Woods</u>

Lacustrine HU's = 4.79.
Riverine HU's = 97.14
Wetland/Waterfowl HU's =18.52

Total Habitat Units =120.45

<u>Alternative 8- Rock Ramp at Wiley and Russell, remove Mill Street and Fish Ladders at Swimming Pool and Pumping Station, In-Stream work at Leyden Woods.</u>

Lacustrine HU's = 3.05
Riverine HU's = 111.07
Wetland/Waterfowl HU's = 4.92
Total Habitat Units =119.04

<u>Alternative 9 - Fish Ladder at Wiley and Russell, Remove Mill Street and Fish Ladder at Swimming Pool and Pumping Station, In stream work for Habitat Restoration at Leyden Woods</u>

Lacustrine HU's = 3.05
Riverine HU's = 108.47
Wetland/Waterfowl HU's = 4.92

Total Habitat Units =116.26

<u>Alternative 10 - Rock Ramp at Wiley and Russell, Fish Ladder at Mill Street, Swimming Pool and Water Supply Dam, and In stream work for Habitat Restoration at Leyden Woods.</u>

Lacustrine HU's = 4.79
Riverine HU's = 97.15
Wetland/Waterfowl HU's = 18.52

Total Habitat Units = 120.46

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Appendix A. Table 1.								
Green River Habitat Restoration - Habitat Units of Optimal Restored Riverine Habitat Available Under Various Project Conditions								
Alternative 1: No Action								
	Value	Weight Multplier	Adjusted Value	Total Score	Total Possible Score	Habitat Index	Habitat Acres	Habitat Units
General Habitat Requisites (Lacustrine)								
DO	0.80	1	0.80			0.40		
Turbidity	0.25	1	0.25					
Temperature	0.50	1	0.50					
Benthic Inverts	0.25	1	0.25					
Cover	0.35	1	0.35					
Forage	0.50	1	0.50					
			0.44	0.40	1			
				0.40	1	0.40		
Specific Habitat Requisites								
Warmwater Species								
Largemouth Bass								
Littoral Habitat	0.50	0.333	0.17					
Spawning Substrate	0.40	0.333	0.13					
Deepwater Habitat	0.40	0.333	0.13					
				0.43	0.999	0.43		
Total HI for Lacustrine Fisheries Component						**0.42**	**11.10**	**4.65**
General Habitat Requisites (Riverine)								
DO	0.75	1	0.75					
Turbidity	0.25	1	0.25					
Temperature	0.50	1	0.50					
Benthic Inverts	0.75	1	0.75					
Cover	0.60	1	0.60					
Forage	0.70	1	0.70	0.56				
Flow	0.70	1	0.70	0.57				
			0.58	0.57	1	0.57		
Specific Habitat Requisites								
Riverine/Anadromous Species								
Brook Trout								
Specific Cover	0.50	0.111	0.06					
Percent Pools	0.60	0.111	0.07					
Spawning Habitat	0.60	0.111	0.07					
	0.00			0.19	0.333	0.19		
Blueback Herring								
Upstream Passage	0.00	0.111	0.00					
Downstream Passage	0.25	0.111	0.03	0.08	0.333	0.08		
Spawning Habitat	0.50	0.111	0.06					
Atlantic Salmon								
Upstream Passage	0.00	0.111	0.00					
Downstream Passage	0.25	0.111	0.03					
Spawning Habitat	0.60	0.111	0.07	0.09	0.333	0.09		
					0.999	0.37		
Total Habitat Index for Riverine Component						**0.46**	**156.76**	**71.91**
Wetland/Waterfowl								
General Requisites								
Emergent Vegetation/scrub shrub	0.70	1	0.70					
Percent Open water < 3 feet deep	0.90	1	0.90					
Percent vegetated open water	0.90	1	0.90					
				0.83	1	0.83		
Specific Habitat Requisites								
Black Duck								
Open Water:Emergent Vegetation, Density	0.90	0.333	0.30					
Percent Backwater	0.90	0.333	0.30					
% Emergent/scrub shrub Within 1 mile of pon	0.90	0.333	0.30	0.90	0.999	0.90		
Total Habitat Index for Waterfowl Component						**0.86**	**21.47**	**18.52**
							189.33	
Total Habitat Units (Habitat Index X Acres)								**95.08**

Green River Habitat Restoration - Habitat Units of Optimal Restored Riverine Habitat
Available Under Various Project Conditions

Alternative 2: Dam Removal at Lower Dams and Fish Ladders at Upper.

	Value	Weight Multplier	Adjusted Value	Total Score	Total Possible Score	Habitat Index	Habitat Acres	Habitat Units
General Habitat Requisites (Lacustrine):								
DO	1.00	1	1.00			0.46		
Turbidity	0.50	1	0.50					
Temperature	0.50	1	0.50					
Benthic Inverts	0.40	1	0.40					
Cover	0.25	1	0.25					
Forage	0.40	1	0.40					
			0.51	0.46	1			
				0.46	1	0.46		
Specific Habitat Requisites								
Warmwater Species								
Largemouth Bass								
Littoral Habitat	0.25	0.333	0.08					
Spawning Substrate	0.50	0.333	0.17					
Deepwater Habitat	0.20	0.333	0.07					
				0.32	0.999	0.32		
Total HI for Lacustrine Fisheries Component						**0.38**	**5.12**	**1.96**
General Habitat Requisites (Riverine):								
DO	1.00	1	1.00					
Turbidity	0.50	1	0.50					
Temperature	0.60	1	0.60					
Benthic Inverts	0.85	1	0.85					
Cover	0.80	1	0.80					
Forage	0.85	1	0.85	0.75				
Flow	1.00	1	1.00	0.78				
			0.77	0.78	1	0.78		
Specific Habitat Requisites								
Riverine/Anadromous Species								
Brook Trout								
Specific Cover	0.70	0.111	0.08					
Percent Pools	0.70	0.111	0.08					
Spawning Habitat	0.80	0.111	0.09					
				0.24	0.333	0.24		
Blueback Herring								
Upstream Passage	0.90	0.111	0.10					
Downstream Passage	0.90	0.111	0.10	0.29	0.333	0.29		
Spawning Habitat	0.80	0.111	0.09					
Atlantic Salmon								
Upstream Passage	0.90	0.111	0.10					
Downstream Passage	0.90	0.111	0.10					
Spawning Habitat	0.90	0.111	0.10	0.30	0.333	0.30		
					0.999	0.83		
Total Habitat Index for Riverine Component						**0.81**	**150.77**	**121.38**
Wetland Restoration								
General Requisites								
Emergent Vegetation/scrub shrub	0.15	1	0.15					
Percent Open water < 3 feet deep	0.25	1	0.25					
Percent vegetated open water	0.15	1	0.15					
				0.18	1	0.18		
Specific Habitat Requisites								
Black Duck	0.00							
Open Water:Emergent Vegetation, Density	0.30	0.333	0.10					
Percent Backwater	0.25	0.333	0.08					
% Emergent/scrub shrub Within 1 mile of pon	0.75	0.333	0.25	0.43	0.999	0.43		
Total Habitat Index for Waterfowl component						**0.28**	**17.73**	**4.92**
							173.62	
Total Habitat Units (Habitat Index X Acres)								**128.26**

Green River Habitat Restoration - Habitat Units of Optimal Restored Riverine Habitat
Available Under Various Project Conditions

Alternative 3: Fish Ladders at 4 Dams

	Value	Weight Multplier	Adjusted Value	Total Score	Total Possible Score	Habitat Index (HI)	Habitat Acres	Habitat Units (HI X Acres)
General Habitat Requisites (Lacustrine)								
DO	0.80	1	0.80			0.42		
Turbidity	0.25	1	0.25					
Temperature	0.50	1	0.50					
Benthic Inverts	0.25	1	0.25					
Cover	0.35	1	0.35					
Forage	0.60	1	0.60					
			0.46	0.42	1			
				0.42	1	0.42		
Specific Habitat Requisites								
Warmwater Species								
Largemouth Bass								
Littoral Habitat	0.50	0.333	0.17					
Spawning Substrate	0.40	0.333	0.13					
Deepwater Habitat	0.40	0.333	0.13					
				0.43	0.999	0.43		
Total Habitat Index for Lacustrine Fisheries Component						**0.42**	**11.10**	**4.72**
General Habitat Requisites (Riverine)								
DO	0.75	1	0.75					
Turbidity	0.25	1	0.25					
Temperature	0.50	1	0.50					
Benthic Inverts	0.75	1	0.75					
Cover	0.60	1	0.60					
Forage	0.80	1	0.80	0.57				
Flow	0.70	1	0.70	0.59				
			0.60	0.59	1	0.59		
Specific Habitat Requisites								
Riverine/Anadromous Species								
Brook Trout								
Specific Cover	0.50	0.111	0.06					
Percent Pools	0.60	0.111	0.07					
Spawning Habitat	0.60	0.111	0.07					
				0.19	0.333	0.19		
Blueback Herring								
Upstream Passage	0.75	0.111	0.08					
Downstream Passage	0.80	0.111	0.09	0.23	0.333	0.23		
Spwaining Habitat	0.50	0.111	0.06					
Atlantic Salmon								
Upstream Passage	0.75	0.111	0.08					
Downstream Passage	0.80	0.111	0.09					
Spawning Habitat	0.60	0.111	0.07	0.24	0.333	0.24		
					0.999	0.65		
Total Habitat Index for Riverine Component						**0.62**	**156.76**	**97.08**
Wetland Restoration								
General Requisites								
Emergent Vegetation/scrub shrub	0.70	1	0.70					
Percent Open water < 3 feet deep	0.90	1	0.90					
Percent vegetated open water	0.90	1	0.90					
				0.83	1	0.83		
Specific Habitat Requisites								
Black Duck								
Open Water:Emergent Vegetation, Density	0.90	0.333	0.30					
Percent Backwater	0.90	0.333	0.30					
% Emergent/scrub shrub Within 1 mile of pon	0.90	0.333	0.30	0.90	0.999	0.90		
Total Habitat Index for Waterfowl component						**0.86**	**21.47**	**18.52**
							189.33	
Total Habitat Units (Habitat Index X Acres)								**120.32**

Green River Habitat Restoration - Habitat Units of Optimal Restored Riverine Habitat								
Available Under Various Project Conditions								
Alternative 4: Rock Ramp fishway at WR and dam removal at Mill Street with Fish ladders at upper.								
	Value	Weight Multplier	Adjusted Value	Total Score	Total Possible Score	Habitat Index	Habitat Acres	Habitat Units
General Habitat Requisites (Lacustrine)								
DO	0.90	1	0.90			0.44		
Turbidity	0.38	1	0.38					
Temperature	0.50	1	0.50					
Benthic Inverts	0.30	1	0.30					
Cover	0.30	1	0.30					
Forage	0.50	1	0.50					
			0.48	0.44	1			
				0.44	1	0.44		
Specific Habitat Requisites								
Warmwater Species								
Largemouth Bass								
Littoral Habitat	0.38	0.333	0.13					
Spawning Substrate	0.45	0.333	0.15					
Deepwater Habitat	0.30	0.333	0.10					
				0.38	0.999	0.38		
Total HI for Lacustrine Fisheries Component						**0.41**	**7.36**	**3.01**
General Habitat Requisites (Riverine)								
DO	0.88	1	0.88					
Turbidity	0.38	1	0.38					
Temperature	0.55	1	0.55					
Benthic Inverts	0.83	1	0.83					
Cover	0.73	1	0.73					
Forage	0.83	1	0.83	0.67				
Flow	0.85	1	0.85	0.70				
			0.70	0.70	1	0.70		
Specific Habitat Requisites								
Riverine/Anadromous Species								
Brook Trout								
Specific Cover	0.65	0.111	0.07					
Percent Pools	0.67	0.111	0.07					
Spawning Habitat	0.70	0.111	0.08					
				0.22	0.333	0.22		
Blueback Herring								
Upstream Passage	0.85	0.111	0.09					
Downstream Passage	0.85	0.111	0.09	0.26	0.333	0.26		
Spwaining Habitat	0.65	0.111	0.07					
Atlantic Salmon								
Upstream Passage	0.85	0.111	0.09					
Downstream Passage	0.85	0.111	0.09					
Spawning Habitat	0.75	0.111	0.08	0.27	0.333	0.27		
					0.999	0.76		
Total Habitat Index for Riverine Component						**0.73**	**153.01**	**111.02**
Wetland Restoration								
General Requisites								
Emergent Vegetation/scrub shrub	0.15	1	0.15					
Percent Open water < 3 feet deep	0.25	1	0.25					
Percent vegetated open water	0.15	1	0.15					
				0.18	1	0.18		
Specific Habitat Requisites								
Black Duck								
Open Water:Emergent Vegetation, Density	0.30	0.333	0.10					
Percent Backwater	0.25	0.333	0.08					
% Emergent/scrub shrub Within 1 mile of pon	0.75	0.333	0.25	0.43	0.999	0.43		
Total Habitat Index for Waterfowl component						**0.28**	**17.73**	**4.92**
							178.10	
Total Habitat Units (Habitat Index X Acres)								**118.94**

Green River Habitat Restoration - Habitat Units of Optimal Restored Riverine Habitat								
Available Under Various Project Conditions								
Alternative 5: Fish Ladder at WR, removal at Mill, Fish ladders at Upper								
	Value	Weight Multplier	Adjusted Value	Total Score	Total Possible Score	Habitat Index	Habitat Acres	Habitat Units
General Habitat Requisites (Lacustrine)								
DO	0.90	1	0.90			0.44		
Turbidity	0.38	1	0.38					
Temperature	0.50	1	0.50					
Benthic Inverts	0.30	1	0.30					
Cover	0.30	1	0.30					
Forage	0.50	1	0.50					
			0.48	0.44	1			
				0.44	1	0.44		
Specific Habitat Requisites								
Warmwater Species	0.00							
Largemouth Bass	0.00							
Littoral Habitat	0.38	0.333	0.13					
Spawning Substrate	0.45	0.333	0.15					
Deepwater Habitat	0.30	0.333	0.10					
				0.38	0.999	0.38		
Total HI for Lacustrine Fisheries Component						**0.41**	**7.36**	**3.01**
General Habitat Requisites (Riverine)								
DO	0.88	1	0.88					
Turbidity	0.38	1	0.38					
Temperature	0.55	1	0.55					
Benthic Inverts	0.80	1	0.80					
Cover	0.70	1	0.70					
Forage	0.80	1	0.80	0.66				
Flow	0.85	1	0.85	0.68				
			0.68	0.68	1	0.68		
Specific Habitat Requisites								
Riverine/Anadromous Species								
Brook Trout								
Specific Cover	0.60	0.111	0.07					
Percent Pools	0.65	0.111	0.07					
Spawning Habitat	0.70	0.111	0.08					
				0.22	0.333	0.22		
Blueback Herring								
Upstream Passage	0.80	0.111	0.09					
Downstream Passage	0.82	0.111	0.09	0.25	0.333	0.25		
Spwaining Habitat	0.65	0.111	0.07					
Atlantic Salmon								
Upstream Passage	0.80	0.111	0.09					
Downstream Passage	0.82	0.111	0.09					
Spawning Habitat	0.75	0.111	0.08	0.26	0.333	0.26		
					0.999	0.73		
Total Habitat Index for Riverine Component						**0.71**	**153.01**	**108.23**
Wetland Restoration								
General Requisites								
Emergent Vegetation/scrub shrub	0.15	1	0.15					
Percent Open water < 3 feet deep	0.25	1	0.25					
Percent vegetated open water	0.15	1	0.15					
				0.18	1	0.18		
Specific Habitat Requisites								
Black Duck								
Open Water:Emergent Vegetation, Density	0.30	0.333	0.10					
Percent Backwater	0.25	0.333	0.08					
% Emergent/scrub shrub Within 1 mile of pon	0.75	0.333	0.25	0.43	0.999	0.43		
Total Habitat Index for Waterfowl component						**0.28**	**17.73**	**4.92**
							178.10	
Total Habitat Units (Habitat Index X Acres)								**116.16**

Green River Habitat Restoration - Habitat Units of Optimal Restored Riverine Habitat									
Available Under Various Project Conditions									
Alternative 6: Dam Removal at WR and MS, fish Ladder at upper dams with Instream at WR and LW									
	Value	Weight Multplier	Adjusted Value	Total Score	Total Possible Score	Habitat Index	Habitat Acres	Habitat Units	Restored Instream Acres
General Habitat Requisites (Lacustrine)									
DO	1.00	1	1.00			0.48			
Turbidity	0.60	1	0.60						
Temperature	0.50	1	0.50						
Benthic Inverts	0.40	1	0.40						
Cover	0.25	1	0.25						
Forage	0.40	1	0.40						
			0.53	0.48	1				
				0.48	1	0.48			
Specific Habitat Requisites									
Warmwater Species									
Largemouth Bass									
Littoral Habitat	0.25	0.333	0.08						
Spawning Substrate	0.50	0.333	0.17						
Deepwater Habitat	0.20	0.333	0.07						
				0.32	0.999	0.32			
Total HI for Lacustrine Fisheries Component						**0.39**	**5.12**	**1.99**	
General Habitat Requisites (Riverine)									
DO	1.00	1	1.00						
Turbidity	0.60	1	0.60						
Temperature	0.60	1	0.60						
Benthic Inverts	0.90	1	0.90						
Cover	0.90	1	0.90						
Forage	0.85	1	0.85	0.79					
Flow	1.00	1	1.00	0.82					
			0.81	0.82	1	0.82			
Specific Habitat Requisites									
Riverine/Anadromous Species									
Brook Trout									
Specific Cover	0.95	0.111	0.11						
Percent Pools	0.95	0.111	0.11						
Spawning Habitat	0.90	0.111	0.10						
				0.31	0.333	0.31			
Blueback Herring									
Upstream Passage	0.90	0.111	0.10						
Downstream Passage	0.90	0.111	0.10	0.29	0.333	0.29			
Spwaining Habitat	0.80	0.111	0.09						
Atlantic Salmon									
Upstream Passage	0.90	0.111	0.10						
Downstream Passage	0.90	0.111	0.10						
Spawning Habitat	0.95	0.111	0.11	0.31	0.333	0.31			
					0.999	0.90			
Total Habitat Index for Riverine Component						**0.86**	**147.03**	**121.59**	**3.73697**
Wetland Restoration									
General Requisites									
Emergent Vegetation/scrub shrub	0.15	1	0.15						
Percent Open water < 3 feet deep	0.25	1	0.25						
Percent vegetated open water	0.15	1	0.15						
				0.18	1	0.18			
Specific Habitat Requisites									
Black Duck									
Open Water:Emergent Vegetation, Density	0.30	0.333	0.10						
Percent Backwater	0.25	0.333	0.08						
% Emergent/scrub shrub Within 1 mile of pon	0.75	0.333	0.25	0.43	0.999	0.43			
Total Habitat Index for Waterfowl component						**0.28**	**17.73**	**4.92**	
							173.62		
Total Habitat Units (Habitat Index X Acres)								**128.50**	

Green River Habitat Restoration - Habitat Units of Optimal Restored Riverine Habitat									
Available Under Various Project Conditions									
Alternative 7: Fish ladder at all dams, instream restoration at Leyden Woods									
	Value	Weight Multplier	Adjusted Value	Total Score	Total Possible Score	Habitat Index	Habitat Acres	Habitat Units	Restored Instream Acres
General Habitat Requisites (Lacustrine)									
DO	0.80	1	0.80			0.43			
Turbidity	0.30	1	0.30						
Temperature	0.50	1	0.50						
Benthic Inverts	0.25	1	0.25						
Cover	0.35	1	0.35						
Forage	0.60	1	0.60						
			0.47	0.43	1				
				0.43	1	0.43			
Specific Habitat Requisites									
Warmwater Species									
Largemouth Bass									
Littoral Habitat	0.50	0.333	0.17						
Spawning Substrate	0.40	0.333	0.13						
Deepwater Habitat	0.40	0.333	0.13						
				0.43	0.999	0.43			
Total HI for Lacustrine Fisheries Component						**0.43**	**11.10**	**4.79**	
General Habitat Requisites (Riverine)									
DO	0.75	1	0.75						
Turbidity	0.30	1	0.30						
Temperature	0.50	1	0.50						
Benthic Inverts	0.78	1	0.78						
Cover	0.63	1	0.63						
Forage	0.80	1	0.80	0.59					
Flow	0.70	1	0.70	0.61					
			0.62	0.61	1	0.61			
Specific Habitat Requisites									
Riverine/Anadromous Species									
Brook Trout									
Specific Cover	0.75	0.111	0.08						
Percent Pools	0.67	0.111	0.07						
Spawning Habitat	0.75	0.111	0.08						
				0.24	0.333	0.24			
Blueback Herring									
Upstream Passage	0.75	0.111	0.08						
Downstream Passage	0.80	0.111	0.09	0.23	0.333	0.23			
Spwaining Habitat	0.50	0.111	0.06						
Atlantic Salmon									
Upstream Passage	0.75	0.111	0.08						
Downstream Passage	0.80	0.111	0.09						
Spawning Habitat	0.65	0.111	0.07	0.24	0.333	0.24			
					0.999	0.71			
Total Habitat Index for Riverine Component						**0.66**	**155.26**	**97.14**	**1.49697**
Wetland Restoration									
General Requisites									
Emergent Vegetation/scrub shrub	0.70	1	0.70						
Percent Open water < 3 feet deep	0.90	1	0.90						
Percent vegetated open water	0.90	1	0.90						
				0.83	1	0.83			
Specific Habitat Requisites									
Black Duck									
Open Water:Emergent Vegetation, Density	0.90	0.333	0.30						
Percent Backwater	0.90	0.333	0.30						
% Emergent/scrub shrub Within 1 mile of pon	0.90	0.333	0.30	0.90	0.999	0.90			
Total Habitat Index for Waterfowl component						**0.86**	**21.47**	**18.52**	
							189.33		
Total Habitat Units (Habitat Index X Acres)								**120.45**	

Green River Habitat Restoration - Habitat Units of Optimal Restored Riverine Habitat										
Available Under Various Project Conditions										
Alternative 8: Rock Ramp at WR, Removal of MS, Fish ladders at upper,instream restoration at Leyden Woods										
	Value	Weight Multplier	Adjusted Value	Total Score	Total Possible Score	Habitat Index	Habitat Acres	Habitat Units	Restored Instream Acres	
General Habitat Requisites (Lacustrine)										
DO	0.90	1	0.90			0.46				
Turbidity	0.45	1	0.45							
Temperature	0.50	1	0.50							
Benthic Inverts	0.30	1	0.30							
Cover	0.30	1	0.30							
Forage	0.50	1	0.50							
			0.49	0.46	1					
				0.46	1	0.46				
Specific Habitat Requisites										
Warmwater Species										
Largemouth Bass										
Littoral Habitat	0.38	0.333	0.13							
Spawning Substrate	0.45	0.333	0.15							
Deepwater Habitat	0.30	0.333	0.10							
				0.38	0.999	0.38				
Total HI for Lacustrine Fisheries Component						**0.41**	**7.36**	**3.05**		
General Habitat Requisites (Riverine)										
DO	0.88	1	0.88							
Turbidity	0.45	1	0.45							
Temperature	0.55	1	0.55							
Benthic Inverts	0.85	1	0.85							
Cover	0.78	1	0.78							
Forage	0.83	1	0.83	0.70						
Flow	0.85	1	0.85	0.72						
			0.72	0.72	1	0.72				
Specific Habitat Requisites										
Riverine/Anadromous Species										
Brook Trout										
Specific Cover	0.85	0.111	0.09							
Percent Pools	0.68	0.111	0.08							
Spawning Habitat	0.85	0.111	0.09							
				0.26	0.333	0.26				
Blueback Herring										
Upstream Passage	0.85	0.111	0.09							
Downstream Passage	0.85	0.111	0.09	0.26	0.333	0.26				
Spwaining Habitat	0.65	0.111	0.07							
Atlantic Salmon										
Upstream Passage	0.85	0.111	0.09							
Downstream Passage	0.85	0.111	0.09							
Spawning Habitat	0.80	0.111	0.09	0.28	0.333	0.28				
					0.999	0.80				
Total Habitat Index for Riverine Component						**0.76**	**151.51**	**111.07**	**1.49697**	
Wetland Restoration	0.00									
General Requisites	0.00									
Emergent Vegetation/scrub shrub	0.15	1	0.15							
Percent Open water < 3 feet deep	0.25	1	0.25							
Percent vegetated open water	0.15	1	0.15							
				0.18	1	0.18				
Specific Habitat Requisites										
Black Duck										
Open Water:Emergent Vegetation, Density	0.30	0.333	0.10							
Percent Backwater	0.25	0.333	0.08							
% Emergent/scrub shrub Within 1 mile of pon	0.75	0.333	0.25	0.43	0.999	0.43				
Total Habitat Index for Waterfowl component						**0.28**	**17.73**	**4.92**		
							178.10			
Total Habitat Units (Habitat Index X Acres)								**119.04**		

Green River Habitat Restoration - Habitat Units of Optimal Restored Riverine Habitat
Available Under Various Project Conditions

Alternative 9: Fish Ladder at WR, Removal of MS, Fish ladders at upper,instream restoration at Leyden Woods

	Value	Weight Multplier	Adjusted Value	Total Score	Total Possible Score	Habitat Index	Habitat Acres	Habitat Units	
General Habitat Requisites (Lacustrine)									
DO	0.90	1	0.90			0.46			
Turbidity	0.45	1	0.45						
Temperature	0.50	1	0.50						
Benthic Inverts	0.30	1	0.30						
Cover	0.30	1	0.30						
Forage	0.50	1	0.50						
			0.49	0.46	1				
				0.46	1	0.46			
Specific Habitat Requisites									
Warmwater Species									
Largemouth Bass									
Littoral Habitat	0.38	0.333	0.13						
Spawning Substrate	0.45	0.333	0.15						
Deepwater Habitat	0.30	0.333	0.10						
				0.38	0.999	0.38			
Total HI for Lacustrine Fisheries Component						**0.41**	**7.36**	**3.05**	
General Habitat Requisites (Riverine)									
DO	0.88	1	0.88						
Turbidity	0.45	1	0.45						
Temperature	0.55	1	0.55						
Benthic Inverts	0.84	1	0.84						
Cover	0.75	1	0.75						
Forage	0.80	1	0.80	0.69					
Flow	0.85	1	0.85	0.71					
			0.71	0.71	1	0.71			
Specific Habitat Requisites									
Riverine/Anadromous Species									
Brook Trout									
Specific Cover	0.80	0.111	0.09						
Percent Pools	0.70	0.111	0.08						
Spawning Habitat	0.85	0.111	0.09						
				0.26	0.333	0.26			
Blueback Herring									
Upstream Passage	0.80	0.111	0.09						
Downstream Passage	0.82	0.111	0.09	0.25	0.333	0.25			
Spwaining Habitat	0.65	0.111	0.07						
Atlantic Salmon									
Upstream Passage	0.80	0.111	0.09						
Downstream Passage	0.82	0.111	0.09						
Spawning Habitat	0.80	0.111	0.09	0.27	0.333	0.27			
					0.999	0.78			
Total Habitat Index for Riverine Component						**0.75**	**151.51**	**108.29**	**1.50**
Wetland Restoration									
General Requisites									
Emergent Vegetation/scrub shrub	0.15	1	0.15						
Percent Open water < 3 feet deep	0.25	1	0.25						
Percent vegetated open water	0.15	1	0.15						
				0.18	1	0.18			
Specific Habitat Requisites									
Black Duck									
Open Water:Emergent Vegetation, Density	0.30	0.333	0.10						
Percent Backwater	0.25	0.333	0.08						
% Emergent/scrub shrub Within 1 mile of pon	0.75	0.333	0.25	0.43	0.999	0.43			
Total Habitat Index for Waterfowl component						**0.28**	**17.73**	**4.92**	
							0.00		
Total Habitat Units (Habitat Index X Acres)								**116.26**	

Green River Habitat Restoration - Habitat Units of Optimal Restored Riverine Habitat
Available Under Various Project Conditions

Alternative 10: Rock Ramp at Wiley Russell, Fish ladder at Mill Street, and Fish ladders at upper,instream restoration at Leyden Woods

	Value	Weight Multplier	Adjusted Value	Total Score	Total Possible Score	Habitat Index	Habitat Acres	Habitat Units	
General Habitat Requisites (Lacustrine)									
DO	0.80	1	0.80			0.43			
Turbidity	0.30	1	0.30						
Temperature	0.50	1	0.50						
Benthic Inverts	0.25	1	0.25						
Cover	0.35	1	0.35						
Forage	0.60	1	0.60						
			0.47	0.43	1				
	0.47			0.43	1	0.43			
Specific Habitat Requisites									
Warmwater Species									
Largemouth Bass									
Littoral Habitat	0.50	0.333	0.17						
Spawning Substrate	0.40	0.333	0.13						
Deepwater Habitat	0.40	0.333	0.13						
				0.43	0.999	0.43			
Total HI for Lacustrine Fisheries Component						**0.43**	**11.10**	**4.79**	
General Habitat Requisites (Riverine)									
DO	0.75	1	0.75						
Turbidity	0.30	1	0.30						
Temperature	0.50	1	0.50						
Benthic Inverts	0.79	1	0.79						
Cover	0.64	1	0.64						
Forage	0.81	1	0.81	0.60					
Flow	0.70	1	0.70	0.61					
			0.62	0.61	1	0.61			
Specific Habitat Requisites									
Riverine/Anadromous Species									
Brook Trout									
Specific Cover	0.78	0.111	0.09						
Percent Pools	0.68	0.111	0.08						
Spawning Habitat	0.75	0.111	0.08						
				0.25	0.333	0.25			
Blueback Herring									
Upstream Passage	0.75	0.111	0.08						
Downstream Passage	0.82	0.111	0.09	0.23	0.333	0.23			
Spwaining Habitat	0.50	0.111	0.06						
Atlantic Salmon									
Upstream Passage	0.75	0.111	0.08						
Downstream Passage	0.82	0.111	0.09						
Spawning Habitat	0.65	0.111	0.07	0.25	0.333	0.25			
					0.999	0.72			
Total Habitat Index for Riverine Component						**0.66**	**155.26**	**97.15**	**1.50**
Wetland Restoration									
General Requisites									
Emergent Vegetation/scrub shrub	0.70	1	0.70						
Percent Open water < 3 feet deep	0.90	1	0.90						
Percent vegetated open water	0.90	1	0.90						
				0.83	1	0.83			
Specific Habitat Requisites									
Black Duck									
Open Water:Emergent Vegetation, Density	0.90	0.333	0.30						
Percent Backwater	0.90	0.333	0.30						
% Emergent/scrub shrub Within 1 mile of pon	0.90	0.333	0.30	0.90	0.999	0.90			
Total Habitat Index for Waterfowl component						**0.86**	**21.47**	**18.52**	
							187.83		
Total Habitat Units (Habitat Index X Acres)								**120.46**	

Variables to be applied to Alternatives										
General Habitat Requisites (Lacustrine)	**Alt 1. No Action**	**Alt 2. Dam R at 2, FL at 2**	**Alt 3. Fish Ladder at 4**	**Alt 4. RR at WR, Rmv MS, FL at up**	**Alt 5. FL at WR, rmv m, FL at up.**	**Alt. 6 Restore all, DR 2, FL upper**	**Alt 7. FL at 4, Instream at LW**	**Alt. 8. RR at WR, Rmv MS,**	**Alt 9. FL at WR, Rmv. MS, FL at**	**Alt. 10 RR at WR, Ladder at**
DO	0.80	1.00	0.80	0.90	0.90	1.00	0.80	0.90	0.90	0.80
Turbidity	0.25	0.50	0.25	0.38	0.38	0.60	0.30	0.45	0.45	0.30
Temperature	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Benthic Inverts	0.25	0.40	0.25	0.30	0.30	0.40	0.25	0.30	0.30	0.25
Cover	0.35	0.25	0.35	0.30	0.30	0.25	0.35	0.30	0.30	0.35
Forage	0.50	0.40	0.60	0.50	0.50	0.40	0.60	0.50	0.50	0.60
	0.44	0.51	0.46	0.48	0.48	0.53	0.47	0.50		0.47
Specific Habitat Requisites										
Warmwater Species										
Largemouth Bass										
Littoral Habitat	0.50	0.25	0.50	0.38	0.38	0.25	0.50	0.38	0.38	0.50
Spawning Substrate	0.40	0.50	0.40	0.45	0.45	0.50	0.40	0.45	0.45	0.40
Deepwater Habitat	0.40	0.20	0.40	0.30	0.30	0.20	0.40	0.30	0.30	0.40
Total HI for Lacustrine Fisheries Component										
General Habitat Requisites (Riverine)										
DO	0.75	1.00	0.75	0.88	0.88	1.00	0.75	0.88	0.88	0.75
Turbidity	0.25	0.50	0.25	0.38	0.38	0.60	0.30	0.45	0.45	0.30
Temperature	0.50	0.60	0.50	0.55	0.55	0.60	0.50	0.55	0.55	0.50
Benthic Inverts	0.75	0.85	0.75	0.83	0.80	0.90	0.78	0.85	0.84	0.79
Cover	0.60	0.80	0.60	0.73	0.70	0.90	0.63	0.78	0.75	0.64
Forage	0.70	0.85	0.80	0.83	0.80	0.85	0.80	0.83	0.80	0.81
Flow	0.70	1.00	0.70	0.85	0.85	1.00	0.70	0.85	0.85	0.70
Specific Habitat Requisites										
Riverine/Anadromous Species										
Brook Trout										
Specific Cover	0.50	0.70	0.50	0.65	0.60	0.95	0.75	0.85	0.80	0.78
Percent Pools	0.60	0.70	0.60	0.67	0.65	0.95	0.67	0.68	0.70	0.68
Spawning Habitat	0.60	0.80	0.60	0.70	0.70	0.90	0.75	0.85	0.85	0.75
Blueback Herring										
Upstream Passage	0.00	0.90	0.75	0.85	0.80	0.90	0.75	0.85	0.80	0.75
Downstream Passage	0.25	0.90	0.80	0.85	0.82	0.90	0.80	0.85	0.82	0.82
Spawning Habitat	0.50	0.80	0.50	0.65	0.65	0.80	0.50	0.65	0.65	0.50
Atlantic Salmon										
Upstream Passage	0.00	0.90	0.75	0.85	0.80	0.90	0.75	0.85	0.80	0.75
Downstream Passage	0.25	0.90	0.80	0.85	0.82	0.90	0.80	0.85	0.82	0.82
Spawning Habitat	0.60	0.90	0.60	0.75	0.75	0.95	0.65	0.80	0.80	0.65
Total Habitat Index for Riverine Component										
Wetland Restoration										
General Requisites										
Emergent Vegetation/scrub shrub	0.70	0.15	0.70	0.15	0.15	0.15	0.70	0.15	0.15	0.70
Percent Open water < 3 feet deep	0.90	0.25	0.90	0.25	0.25	0.25	0.90	0.25	0.25	0.90
Percent vegetated open water	0.90	0.15	0.90	0.15	0.15	0.15	0.90	0.15	0.15	0.90
Specific Habitat Requisites										
Black Duck										
Open Water:Emergent Vegetation, Density	0.90	0.30	0.90	0.30	0.30	0.30	0.90	0.30	0.30	0.90
Percent Backwater	0.90	0.25	0.90	0.25	0.25	0.25	0.90	0.25	0.25	0.90
% Emergent/scrub shrub Within 1 mile of pon	0.90	0.75	0.90	0.75	0.75	0.75	0.90	0.75	0.75	0.90
Total Habitat Units for Each Alternative	**95.08**	**128.26**	**120.32**	**118.94**	**116.16**	**128.50**	**120.45**	**119.04**	**116.26**	**120.46**

APPENDIX 5 – Real Estate Report

US Army Corps of Engineers ®
New England District

New England District
U.S. Army corps of Engineers
696 Virginia Road
Concord, Massachusetts 01742-2751

Real Estate Planning Report
Deerfield River Watershed Feasibility Study
Greenfield, Massachusetts

PREPARED BY: ______________________________
A. MARY DUNN
STAFF APPRAISER

JUNE 2005

REAL ESTATE REPORT FOR THE DEERFIELD RIVER FEASIBILITY STUDY GREENFIELD, MASSACHUSETTS

1. PURPOSE: The Deerfield River provides some of the most pristine river habitats in Massachusetts and Vermont. Much of the watershed remains fairly undeveloped and has not experienced some of the large-scale degradation of water quality and fish and wildlife habitat as some of the other watersheds. However, the Deerfield River has a large number of dams. There are 45 separate impoundments in the watershed, with 15 of them still generating power (8 are located in Massachusetts). Most of the dams are abandoned mill dams that are currently not in use, many of those are in disrepair. The construction of dams and other structures along the river has resulted in the loss of fish populations. Spawning substrate, wetlands, and forested riparian habitat has been lost to impoundments. As a consequence of industrial development, floodplain encroachment, water pollution, dam construction, and river regulation, many miles of habitat were either reduced or eliminated.

This study was initiated to identify potential restoration areas and the means to restore degraded habitats. The authority for this study is in a United States Senate Resolution Committee on Public Works, adopted on 11 May 1962 (Section 3 of the Rivers and Harbors Act, approved 12 June 1902). The construction of this project would be under Section 206 of the Water Resources Development Act of 1996 that provides authority for the Corps to restore aquatic ecosystems.

2.a. PROJECT AREA DESCRIPTION: The Deerfield River watershed headwaters are in south central Vermont and join the Connecticut River in Greenfield, Massachusetts. The total drainage area is about 665 square miles (350 square miles in Massachusetts and 315 square miles in Vermont). The total river length is 70.2 miles. Major tributaries to the Deerfield River are the North River, Green River, Chickley River, and the Cold River.

The construction of dams and other structures along the river has resulted in the prevention of migratory and resident fish from accessing historic spawning and nursery habitat areas and has resulted in the loss of fish populations. Spawning substrate, wetlands, and forested riparian habitat have been lost to impoundments. A reconnaissance study was done to identify potential restoration areas and the means to restore degraded habitats. The following three areas of aquatic ecosystem restoration were investigated.

A. Restoration of Riverine Migratory Corridors.

River impediments, primarily in the form of dams, causes the loss of spawning habitat for migrating fish (e.g., removal of pool-riffle pattern, elimination of in-stream cover and riparian vegetation, and establishment of unsuitable flow and water depths). The dams also block the migration of anadromous fish upstream to spawning areas and smolt movement to the ocean. They can impede or prevent catadromous fish, which typically live in fresh water and spawn in the ocean, from accessing their primary habitat. The segmenting of the river has also impacted potamodromous fish, which are freshwater species that move to faster moving streams in the watershed to spawn. Impounding the river also causes the loss of spawning habitat for migrating fish (for example, removal of pool-riffle pattern, loss of gravel beds, elimination of in-stream cover and riparian vegetation, and establishment of unsuitable flow regimes and water depths).

The restored passage would benefit the Atlantic salmon, American shad, gizzard shad, blueback herring, sea lamprey, and American eel. Other native species that would benefit from fish passage by providing improved access for pawning include the brown trout, rainbow trout, brook trout, common carp, white perch, white sucker, bluegill, yellow perch, redbreast sunfish, and walleye.

B. Aquatic Free Flowing (Lotic) Habitat Restortions.

Removal of dams and migratory obstructions also offers the opportunity to restore free-flowing habitats such as riffle pool complexes, re-establish gravel beds and similar spawning habitats, increase riparian shade to improve water column temperatures, and create reef habitat structures.

C. Restoration of Riverine Wetlands and Riparian Canopy.

Location of Restoration Sites: The following are several potential fish passage restoration sites in the Deerfield River watershed:

Wiley & Russell Dam: Located in Greenfield on the Green River, 1.2 miles above its confluence with the Deerfield River. This dam, a timber crib and concrete construction, was formerly owned and used by a defunct tap and die complex adjacent to the site. The Massachusetts Department of Environmental Management issued order to the town of Greenfield, present owner of the dam, to repair the dam. The site will be assessed for dam removal, a partial breach, or a fish ladder to restore passage. Removal or passage would provide 0.3 miles of additional riverine habitat along the Green River.

Mill Street Dam: Located in Greenfield on the Green River, 1.5 miles above its confluence with the Deerfield River. This is a concrete dam that was originally owned and used by Greenfield Electric Light and Power abut is now owned by the town of Greenfield. The Mill Street Bridge, which was recently reconstructed, spans two abutments that form the western and eastern edges of the dam. The dam appears to be in good condition. The site would be assessed for dam removal, a partial breach, or a fish ladder to restore passage. Removal or passage would provide 2.2 miles of additional riverine habitat along the Green River.

Swimming Pool Dam: Located along the Green River, about 3.7 miles above its confluence with the Deerfield River. The dam is owned by the town of Greenfield and currently used for recreational purposes (swimming). The dam appears to be in good condition. The site would be assessed for either a notch in one of the spillways or a fish ladder to restore passage. Modification would provide 4.6 miles of additional riverine habitat along the Green River.

Leyden Woods: There is no dam at this location. This is the site of proposed measures to create pools and riffles in-stream of the Green River, near the Leyden Woods Apartment complex, located off Leyden Road. The work would consist of the placement of 11 J-weirs along about 1,000-foot stretch of the Green River near the Leyden Woods apartments. These will be placed at approximately 100-foot intervals at opposing sides of the river about 100 feet downstream of the end of a dirt road/access trail which leads to the river from the field abutting the Leyden Woods property and continues downstream (about 1,000 feet). The J-weirs will be placed in an alternating pattern on each bank. Pole plantings may be used in some sections to help stabilize eroding banks in the area.

Water Supply (a.k.a. Pumping Station) Dam: This is a new concrete dam about 14 feet in height, located along the Green River about 8.3 miles above its confluence with the Deerfield River. It is owned by the town of Greenfield and used for water supply purposes. The dam appears to be in very good condition. Access would be required to construct a fish ladder. This measure would provide 12 miles of additional fish habitat along the Green River.

2.b. RECOMMENDED PLAN: The recommended plan is to remove the Wiley & Russell and Mill Street Dams and install fish passage structures at Swimming Pool Dam and Pumping Station Dam and construct J-weirs at Leyden Woods to enhance aquatic habitat.

2.c. OWNERSHIPS: The town of Greenfield owns the Wiley & Russell Dam and also owns in fee the adjoining property which will be used for the storage/staging area. The town also owns in fee another adjoining property which, along with a privately-owned property, will be used for access. Thus, a temporary easement over 3.77 acres of land for a term of one year are required at this site.

The town of Greenfield owns the Mill Street Dam. The storage/staging area and access area will be on 2 private properties. Thus, a temporary easement over 1 acre of land for a term of one year are required at this site.

The town of Greenfield owns Swimming Pool Dam and the town also owns in fee the adjoining property that will be used for a storage/staging area and for access. Thus, a temporary easement over 1.75 acres of land for a term of one year are required at this site.

The In-Stream Restoration of the Green River at Leyden Woods will be done using the adjoining lot, that the town of Greenfield owns in fee, for a working area and a private lot for the a storage/staging area and for access from Leyden Road. Thus, a temporary easement over 2.75 acres of land for a term of one year are required at this site.

The town of Greenfield owns Pumping Station Dam, located on the Green River, near the Colrain town boundary line. The town of Greenfield also owns in fee the two adjoining lots that will be used for a storage/staging area and for access. Thus, a temporary easement over 1.5 acres of land for a term of one year are required for this site.

The local sponsor is responsible for acquiring all the lands, easements, rights of way, relocations and dredging or excavated material disposal area (LERRD's) needed for this project.

3. DESCRIPTION OF NON-FEDERAL SPONSOR'S EXISTING OWNERSHIP: The non-Federal sponsor does not own any of the lands needed for this project. However, all of the dams are owned by the Town of Greenfield, a project partner.

4. RECOMMENDED ESTATES: The estate that will be utilized for this project is a Standard Temporary Work Area Easement (Estate No. 15). The term of the easements is one year. In addition, a Non-Standard Estate for the fish ladder to be constructed at Swimming Pool Dam and Pumping Station Dam, if needed, is required. A sample of this estate (to be staffed through USACE for approval) is as follows:

"A perpetual and assignable right and easement to construct, maintain, repair, rehabilitate, operate, patrol, replace and remove a fishway and ladder, including all appurtenances thereto, in connection with the Swimming Pool Dam and Pumping Station Dam projects; reserving, however, to the owners, their heirs and assigns, all such rights and privileges in the land as may be used without interfering with or abridging the rights and easements thereby acquired."

5. EXISTING FEDERAL PROJECTS: There are no current Federal projects in the subject project areas.

6. EXISTING FEDERAL OWNERSHIP: There are no federally owned lands in the subject project areas.

7. NAVIGATION SERVITUDE: Navigation servitude does not apply.

8. REAL ESTATE MAPPING: Preliminary maps showing the five study areas and the properties needed for access or for storage/staging areas are attached. However, detailed maps will be prepared at a later date.

9. INDUCED FLOODING: The project will not cause any flooding of other non-project lands.

10. BASELINE COST ESTIMATE FOR REAL ESTATE: The value estimates provided are for all the real estate identified as needed for the five project areas. Credit for the real estate will be determined through the cost-sharing agreement. The breakdown is as follows:

Wiley & Russell Dam: Three parcels of land, totaling approximately 3.77 acres of land, are required. Two are owned by the town of Greenfield in fee and 1 is under private ownership. The value of a 1-year easement over 3.77 acres is $14,000.

Mill Street Dam: Two parcels of land, encompassing approximately one acre of land, are required. Both parcels are under private ownership. The value of a 1-year easement is $20,000.

Swimming Pool Dam: About 1.75 acres of land, a portion of a 20.1 acre parcel, are required for the temporary 1 year easements and approximately 1,600 sq. ft. are needed for the fish ladder easement. The land is owned in fee by the town of Greenfield. The value of a 1-year easement is $5,000 and the value of the fish ladder easement is $1,000.

Leyden Woods: About 2.75 acres of land, portions of two parcels, are required for the in-stream remediation of this area, one of the parcels is owned in fee by the town of Greenfield and the other parcel is under private ownership. The value of a 1-year easement is $5,000.

Water Supply Dam: About 1.5 acres of land, portions of two parcels, are required for the temporary work to be done at this site; Approximately 4,200 sq. ft. is needed for the fish ladder easement and an additional 3,800 sq. ft. is needed for access to the fish ladder. All parcels are owned in fee by the town of Greenfield. The value of a 1-year easement is $7,000. The value of the permanent easements is $3,000.

The administrative costs associated with the temporary easement acquisitions, such as title work, mapping, and closing, are estimated to be $5,000 per ownership. The sponsor has been informed that detailed records have to be kept in order to receive credit for these costs.

Following are the estimates costs for this project:

Temporary easements over 10.77 acres (5 sites) for 1 year	$51,000
Permanent Easements	$ 4,000
Contingency, 25%	$13,750
Total land costs, rounded	$68,750
Total acquisition costs for 10 sites	$50,000
Total real estate costs	$118,750
Total Estimated Real Estate Costs, rounded	$119,000

11. PUBLIC LAW 91-646 RELOCATIONS: There are no potential Public Law 91-646 relocations required in connection with this project. There are no residences or businesses which would be relocated under P.L.91-646. The sponsor has been advised of P.L. 91-646 and the requirement to document expenses.

12. MINERAL AND/OR TIMBER ACTIVITY: There is no present or anticipated mineral or timber harvesting activity in the vicinity of the project that may affect the operation thereof.

13. ASSESSMENT OF NON-FEDERAL SPONSOR'S REAL ESTATE ACQUISITION CAPABILITIES: The Non-Federal sponsor is the Commonwealth of Massachusetts Executive Office of Environmental Affairs. The Sponsor must provide all lands, easements, rights of way, relocations and dredged or excavated material disposal area (LERRDs) required for construction and maintenance of the project at no cost to the Federal Government.

The Assessment of Non-Federal Sponsor's Real Estate Acquisition Capability check is included.

14. ZONING CHANGES: No zoning changes are proposed in lieu of, or to facilitate, real estate acquisitions.

15. ACQUISITION SCHEDULE: The following is the estimated acquisition schedule:

a. PCA EXECUTION – February 2007
b. Forward maps to sponsor – March 2007
c. Survey – N/A
d. Title – April 2007
e. Appraisals – May 2007
f. Closings – June 2007
g. Possession – June 2007
h. LER Certification – December 2007

16. FACILITIES AND UTILITIES RELOCATIONS: The proposed project will not require any utility and/or facility relocations.

17. HAZARDOUS, TOXIC, AND RADIOACTIVE WASTE: There is no knowledge of any contamination on the site. An Environmental Assessment and a Finding of No Significant Impact will be completed on this project. It is anticipated that the proposed project will not result in an adverse impact on the environment.

18. LANDOWNER SENTIMENT: Ecosystem restoration of the Deerfield River (the Green River is one of the tributaries of the Deerfield River) is a high priority for the Federal, state, and local governments. The Commonwealth of Massachusetts and the town of Greenfield are very supportive of this project.

19. OTHER REAL ESTATE ISSUES: The Massachusetts Office of Historic Preservation (SHPO) will conduct an investigation to identify potential significant prehistoric and archaeological sites. They will also provide an assessment of any cultural resource concerns or impacts for the proposed project and a description of the areas for National Historic Preservation Act (NHPA).

WILEY & RUSSELL DAM
Photograph taken by A. M. Dunn on 12/15/04

View of the Wiley & Russell Dam, located on the Green River, a tributary of the Deerfield River

WILEY & RUSSELL DAM
Photograph taken by A. M. Dunn on 12/15/04

Proposed Staging Area for the Wiley & Russell Dam Project

MILL STREET DAM
Photograph taken by A. M. Dunn on 12/15/04

View of the Mill Street Dam

MILL STREET DAM
Photograph taken by A. M. Dunn on 12/15/04

Proposed staging area for Mill Street Dam

SWIMMING POOL DAM
Photograph taken by A. M. Dunn on 12/15/04

Swimming Pool Dam

SWIMMING POOL DAM
Photograph taken by A. M. Dunn on 12/15/04

Proposed staging area on town parking lot

LEYDEN WOODS
Photograph taken by A. M. Dunn on 12/15/04

Area proposed for in-stream restoration

LEYDEN WOODS
Photograph taken by A. M. Dunn on 12/15/04

Proposed Staging Area for Leyden Woods In-Stream Restoration

WATER SUPPLY DAM
Photograph taken by A. M. Dunn on 12/15/04

Water Supply Dam (a.k.a. Pumping Station Dam), located near the covered bridge, on the Green River near the town of Colrain boundary line

WATER SUPPLY DAM
Photograph taken by A. M. Dunn on 12/15/04

View of Covered Bridge (bridge is closed temporarily) on left side of picture; the dam is below fence on the right side of photograph

WATER SUPPLY DAM
Photograph taken by A. M. Dunn on 12/15/04

Proposed staging area for the Water Supply Dam project

Appendix 6

Cost Estimate for Recommended Alternative

Deerfield River, Greenfield, MA
This project consists of
removal of two dams and
installation of fish ladders at
two dams.

Designed By: CENAE
Estimated By: Robert Zwahlen 6/10/04

Prepared By: Updated by Mike Remy 10/4/06

Preparation Date: 06/21/04
Effective Date of Pricing: 06/21/09
Est Construction Time: 200 Days

Sales Tax: 0.0%

Currency in DOLLARS

LABOR ID: MAREAL EQUIP ID: NAT99A

CREW ID: NAT01A UPB ID: UP01EA

Original estimate 6/21/04 - The project is located along the Green River in Greenfield, MA. The goal of the project is to provide access for fish swimming upstream by installing fish ladders in two existing dams or by removing two existing dams.

The following were factored into the estimate.

Field Overhead	- 10%
Home Office OH	- 6%
Profit	- 10%
Contingency	- 25%
Escalation	- 4%
S&A	- 8%

Revised: 10/05/06:

1.Revised estimate labor rates to 2006 Davis Bacon Labor Rates for Greenfield/Franklin county.

2. Added additional cost for removing approximately 150 LF of 8" sewer pipe located underwater at Mill St. Dam , and installation of new pipe in a nearby location at a greater depth than previously. Also included in this additional work are the costs for two new manholes and water diversion/cofferdam during installation.

3. Increased backfill material concrete material unit costs to todays prices.

4. Added escalation factor of 3% per year for three years because project is not likely to be constructed until FY 2009. Total escalation now set at 13%.

** PROJECT DIRECT SUMMARY - Contract (Rounded to 100's) **

	QUANTY UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT
01 PLANNING AND PERMITS	1.00 EA	1,000	16,900	15,000	5,300	15,000	52,200	52234
05 DAMS	1.00 EA	9,800	415,600	99,800	231,100	800	747,300	747304
TOTAL Deerfield River, Greenfield, MA	1.00 EA	10,800	432,500	114,800	236,500	15,800	799,500	799538
Prime Contractor's Field Overhead	10.00 %						80,000	
SUBTOTAL							879,500	
Prime's Home Office Expense	6.00 %						52,800	
SUBTOTAL							932,300	
Prime Contractor's Profit	10.00 %						93,200	
SUBTOTAL							1,025,500	
Prime Contractor's Bond	1.50 %						15,400	
TOTAL INCL INDIRECTS							1,040,900	
Contingency	25.00 %						260,200	
SUBTOTAL							1,301,100	
Escalation	13.00 %						169,100	
SUBTOTAL							1,470,200	
Construction Mgt	8.00 %						117,600	
TOTAL INCL OWNER COSTS							1,587,800	

** PROJECT DIRECT SUMMARY - Feature (Rounded to 100's) **

	QUANTY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT
01 PLANNING AND PERMITS									
01_01 Project Planning			0	16,000	0	0	0	16,000	
01_07 Temporary Permits			0	0	0	0	15,000	15,000	
01_12 Mob and, Demobilization			1,000	900	15,000	5,300	0	21,200	
TOTAL PLANNING AND PERMITS	1.00	EA	1,000	16,900	15,000	5,300	15,000	52,200	52234
05 DAMS									
05_ 5 MILL STREET DAM	1.00	EA	3,800	157,000	46,600	76,100	0	279,700	279738
05_10 WILLEY AND RUSSELL ST DAMS	1.00	EA	2,100	85,300	16,300	50,200	300	152,100	152052
05_15 SWIMMING POOL DAM	1.00	EA	1,200	56,600	14,400	25,600	0	96,500	96515
05_20 WATER SUPPLY DAM	1.00	EA	2,600	116,600	22,500	79,300	500	219,000	218999
TOTAL DAMS	1.00	EA	9,800	415,600	99,800	231,100	800	747,300	747304
TOTAL Deerfield River, Greenfield, MA	1.00	EA	10,800	432,500	114,800	236,500	15,800	799,500	799538
Prime Contractor's Field Overhead	10.00	%						80,000	
SUBTOTAL								879,500	
Prime's Home Office Expense	6.00	%						52,800	
SUBTOTAL								932,300	
Prime Contractor's Profit	10.00	%						93,200	
SUBTOTAL								1,025,500	
Prime Contractor's Bond	1.50	%						15,400	
TOTAL INCL INDIRECTS								1,040,900	
Contingency	25.00	%						260,200	
SUBTOTAL								1,301,100	
Escalation	13.00	%						169,100	
SUBTOTAL								1,470,200	
Construction Mgt	8.00	%						117,600	
TOTAL INCL OWNER COSTS								1,587,800	

** PROJECT DIRECT SUMMARY - Sub Feat (Rounded to 100's) **

	QUANTY UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT
01 PLANNING AND PERMITS								
01_01 Project Planning		0	16,000	0	0	0	16,000	
01_07 Temporary Permits		0	0	0	0	15,000	15,000	
01_12 Mob and, Demobilization		1,000	900	15,000	5,300	0	21,200	
TOTAL PLANNING AND PERMITS	1.00 EA	1,000	16,900	15,000	5,300	15,000	52,200	52234
05 DAMS								
05_ 5 MILL STREET DAM								
05_ 5. 2 Relocate Sewer Line	1.00 EA	700	28,900	17,500	12,600	0	59,000	59033
05_ 5. 5 Earthwork	1.00 EA	1,100	45,900	16,700	25,000	0	87,600	87576
05_ 5.01 Erosion Control	1.00 EA	100	2,400	100	1,600	0	4,100	4092.82
05_ 5.11 Dam Removal	1.00 EA	1,900	79,800	12,200	37,000	0	129,000	129036
TOTAL MILL STREET DAM	1.00 EA	3,800	157,000	46,600	76,100	0	279,700	279738
05_10 WILLEY AND RUSSELL ST DAMS								
05_10. 5 Earth Work		400	15,200	5,600	49,500	0	70,200	
05_10.10 Erosion Control		0	300	0	700	300	1,300	
05_10.25 Dam removal	3700.00 TON	1,800	69,800	10,700	0	0	80,500	21.76
TOTAL WILLEY AND RUSSELL ST DAMS	1.00 EA	2,100	85,300	16,300	50,200	300	152,100	152052
05_15 SWIMMING POOL DAM								
05_15. 5 Earthwork	1.00 EA	200	8,800	3,700	3,100	0	15,700	15650
05_15.10 Erosion Control	1.00 EA	0	800	0	900	0	1,700	1705.05
05_15.15 Fish Ladder	1.00 EA	1,000	47,000	10,700	21,500	0	79,200	79160
TOTAL SWIMMING POOL DAM	1.00 EA	1,200	56,600	14,400	25,600	0	96,500	96515
05_20 WATER SUPPLY DAM								
05_20. 5 Earthwork & Bridge/Culverts	1.00 EA	500	22,500	7,300	30,000	0	59,800	59813
05_20.10 Erosion Control	1.00 EA	0	1,500	0	1,400	500	3,500	3475.46
05_20.15 Fish Ladder	1.00 EA	2,100	92,600	15,200	47,900	0	155,700	155710
TOTAL WATER SUPPLY DAM	1.00 EA	2,600	116,600	22,500	79,300	500	219,000	218999
TOTAL DAMS	1.00 EA	9,800	415,600	99,800	231,100	800	747,300	747304
TOTAL Deerfield River, Greenfield, MA	1.00 EA	10,800	432,500	114,800	236,500	15,800	799,500	799538

APPENDIX 7 – Public Comments Received on Draft Report

US Army Corps
of Engineers®
New England District

News release

Date: Feb. 16, 2007
For Immediate Release
Release No. MA 2007-018
Contact Tim Dugan 978-318-8264
timothy.j.dugan@usace.army.mil
696 Virginia Road, Concord, Massachusetts 01742-2751

Corps proposes environmental restoration to improve fish habitat on Green River in Greenfield

CONCORD, Mass. – The U.S. Army Corps of Engineers, New England District is proposing an environmental restoration project to improve fish habitat as part of the Deerfield River Watershed Study focusing on four dams on the Green River in Greenfield, Mass.

The Massachusetts Executive Office of Environmental Affairs and the City of Greenfield are the non-federal project sponsors.

"Four dams create impoundments along 8.7 miles of the Green River from its confluence with the Deerfield River," said Project Manager David Larsen, of the Corps' New England District, Engineering/Planning Division. "The dams have degraded fisheries and riverine habitats."

The dams block the upstream migration of pre-spawning adult anadromous fish to their historic spawning areas and the downstream migration of adults and juvenile fish to the ocean. Also, the dams preclude catadromous fish, which live in freshwater and spawn in the ocean, from accessing their primary habitat.

"The sectioning of the river also impacts freshwater fish that move to faster flowing streams in the watershed to spawn," Larsen said. The impoundment created by the dams reduce the area of spawning habitat for anadromous and riverine fish by removing pool riffle patterns, eliminating in-stream cover, and maintaining unsuitable flow regimes and water depth.

The recommended plan consists of the removal of the Wiley & Russell and Mill Street Dams and installation of fish passage structures at Swimming Pool Dam and Pumping Station Dam. The recommended plan would extend migratory and spawning habitat for anadromous fish over a distance of 30 river miles. The estimated implementation cost of the recommended plan is

-- more --

approximately $2 million, which would be cost-shared 65 Federal and 35 percent non-Federal. Operations and maintenance of the project would be a non-Federal responsibility and are estimated to cost $12,000 per year over the 50-year life of the project.

Fish species that would benefit from improved fish passage and habitat restoration include Atlantic salmon, American shad, blueback herring, sea lamprey and American eel. Other species that would benefit include brown trout, rainbow trout, brook trout, white sucker, redbreast sunfish, bluegill and yellow perch.

The study considered alternative methods to restore fish passage at each of the dams along the Green River including dam removal, rock ramp fishway, and fish ladder. In addition, the study considered in-stream habitat restoration at certain sites on the river; however, the habitat value of improvements they offered did not compare well with those associated with fish passage.

The Corps prepared an Environmental Assessment for the environmental restoration project. Impacts to Essential Fish Habitat in the project area were avoided or minimized to the maximum extent practicable through the planning and design process. Coordination with the U.S. Fish and Wildlife Service has indicated that no federally listed or proposed, threatened or endangered species under its jurisdiction are known to occur in the study area, with the exception of occasional transient bald eagles. Coordination with the National Marine Fisheries Service indicated that there are no threatened or endangered species expected to be present within that region of the Connecticut River Watershed.

The Green River is considered archaeologically sensitive for the presence of prehistoric archaeological sites. The Wiley & Russell Dam was determined to be a contributing element to the Greenfield Tap and Die Plant No. 1, a district eligible for the National Register. The Green River was used for hydropower for other industries during Greenfield's history. The other three dams considered in this study are not eligible for the National Register.

The Corps will continue coordination with the state historic preservation office and the tribal historic preservation offices to consult on eligibility/non-eligibility of the Wiley & Russell Dam, and to make a determination of effect for the project as a whole.

-- more --

Corps proposes environmental restoration on Green River/3-3-3-3-3

The proposed environmental restoration project is being coordinated with the following Federal, state, tribal and local agencies: U.S. Fish and Wildlife Service, U.S. Environmental Protection Agency, National Marine Fisheries Service, the Massachusetts Department of Environmental Protection, the Massachusetts Department of Conservation and Recreation, the Massachusetts Department of Fish and Game, the Massachusetts Executive Office of Environmental Affairs, the Massachusetts Historical Preservation Office, the Narragansett Tribal Historic Preservation Officer, the Stockbridge-Munsee Tribal Historic Preservation Officer, the Wampanoag Tribal Historic Preservation Officer, the City of Greenfield, and the Franklin Regional Council of Governments.

Public comments on this proposed environmental restoration project should be forwarded no later than March 16, 2007 to the U.S. Army Corps of Engineers, New England District, Engineering/Planning Division (ATTN: Mr. David Larsen), 696 Virginia Road, Concord, MA 01742-2751.

Deerfield River Watershed Association

P.O. Box 13 Shelburne Falls, MA 01370
drwa@deerfieldriver.org www.deerfieldriver.org

DRWA

February 22, 2007

Attn: David Larsen, Engineering/Planning Division
District Engineer
696 Virginia Road
Concord, MA 01742-2751

Dear David:

As you know, the Deerfield River Watershed Association (DRWA) has been closely involved in the Green River Dams Study through our participation in the Deerfield River Watershed Team.

We are pleased to see the Public Notice on the Deerfield River Watershed Study, Green River Fish Passage and Ecosystem Restoration, Greenfield, Massachusetts posted at this time and offer our comments.

DRWA values the Green River as a cold water resource and home to migratory fish. We are thrilled that salmon have made it back up to the Green River in recent years and hope that in the future they can reach their spawning grounds.

We have read your project description and support the recommended plan to remove the Wiley Russell and the Mill Street dams and to install fish passages at the Swimming Pool and the Pumping Station dams.

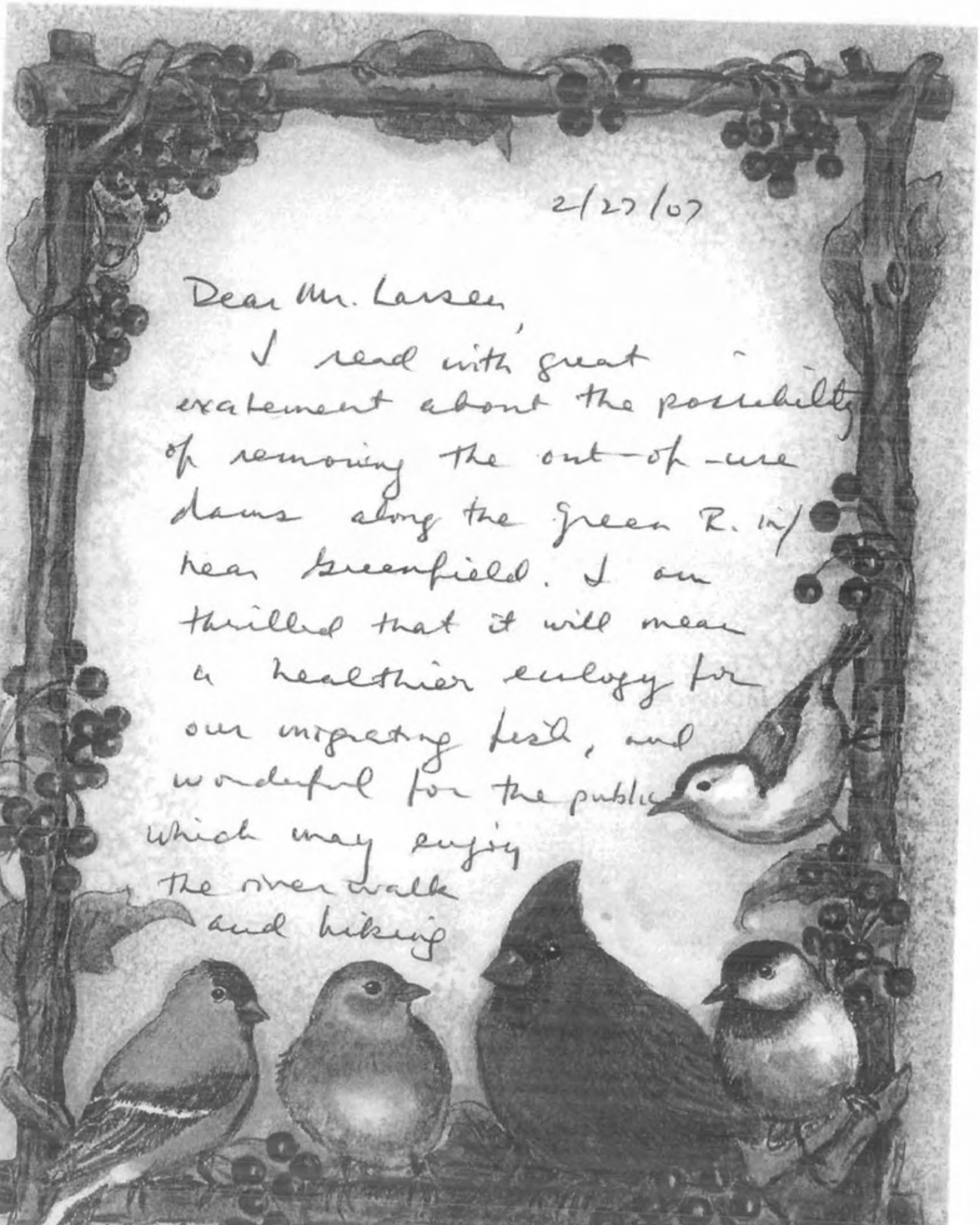
Our only concern is that more detailed study is needed of the sediment accumulated behind the Wiley Russell dam, and that any polluted sediment be removed if it is found that it could harm wildlife and human use of the Green and Deerfield Rivers downstream.

Best regards,

MFWalk

Marie-Françoise Walk
President

Marie-Françoise Walk
President



2/27/07

Dear Mr. Larsen,

I read with great excitement about the possibility of removing the out-of-use dams along the Green R. in/near Greenfield. I am thrilled that it will mean a healthier ecology for our migrating fish, and wonderful for the public which may enjoy the river walk and hiking along its shores in the future.

My great-grandfather was F.O. Wells who was an owner of GTD on Meridian St. and benefitted from one of its dams. As the only relative of his living nearby, I urge you that I don't think it is important to keep that dam because of its historical significance. The fish and today's people need a free flowing river.

Thanks for taking my thoughts into consideration.

Pamela W. Walker
Shelburne Falls

United States Department of Agriculture

NRCS

Natural Resources Conservation Service
451 West Street
Amherst, MA 01002

413-253-4350
fax 413-253-4375
www.ma.nrcs.usda.gov

March 1, 2007

David Larson
District Engineer
Engineering/Planning Division
U.S. Army Corps of Engineers
New England District
696 Virginia Road
Concord, Massachusetts 01742-2751

RE: Deerfield River Watershed Study
Green River Fish Passage and Ecosystem Restoration
Greenfield, Massachusetts

Dear Mr.Larson:

The USDA Natural Resources Conservation Service (NRCS) supports the proposed Green River Fish Passage and Ecosystem Restoration project, in Greenfield, Massachusetts.

The proposed study is consistent with the NRCS mission and objectives. Stream corridor restoration is a key conservation practice for our Agency's Mission Goal of Healthy Plant and Animal Communities identified in our strategic plan for 2005-2010. Locally, our Massachusetts plan of operations for the Wildlife Habitat Improvement Program (WHIP) encourages restoration of fish passage as a priority measure.

We look forward to viewing the project details as they are developed. Our point of contact is Richard J. DeVergilio, State Resource Conservationist. Mr. DeVergilio may be reached at (413) 253-4379 or email: rick.devergilio@ma.usda.gov.

Sincerely,

Christine Clarke

Christine Clarke
State Conservationist

cc: R. DeVergilio, SRC, NRCS, Amherst, MA

12 March 2007

District Engineer
U.S. Army Corps of Engineers: New England District
696 Virginia Road
Concord MA 01742-2751
Attn: Engineering/Planning Division

RE: Green River Passage and Ecosystem Restoration

Dear Sirs;

Please accept the following comments with respect to the Corps proposal for fish passage actions affecting four dams on an 8.7mile segment of the Green River in the town of Greenfield.

This proposal recommends removal of the Wiley & Russell and Mill Street dams, and installation of fish passage structures at the Green River Recreation Area and Pumping Station dams. The project would entail a 35% non-Federal cost share of project costs, with 65% from Federal sources. Annual maintenance costs are estimated at $12,000. per year.

The study fails to adequately consider the historic, cultural and related economic development values of the two dams proposed for removal. These are unique and highly significant local, regional and national assets. Alternatives to complete removal could accomplish both natural resource and cultural goals and, therefore it is not clear why a balanced solution is not recommended.

The Wiley & Russell (Bascom) Dam is associated with the nationally significant John Russell "Green River" Works, its successor Wiley & Russell, and the international precision technology leader, Greenfield Tap & Die Corporation whose use of the dam extended from 1833 to 1965. As a powerful component of the industry that most profoundly shaped Greenfield, this dam has enormous capacity to promote pride in community and to become a focus attraction for the Mead Street Walkway. Its visual quality has led to repeated use in print, giving it iconic status.
As you know, the Commission also proposes that interpretation of the dam and this segment of the Green River will fulfill the town's outstanding obligations under an MOA with the Massachusetts Historical Commission.

The Mill (River) Street power site is associated with the first site of the J. Russell Cutlery works, the seminal 1787 William Moore six story mill which the Survey terms "An industrial empire". It attracted nationally known craftsmen to Greenfield. The present brick mill which housed the innovative Wells Company and the Steel Stamp Company is the oldest surviving mill in town.

The MHC Reconnaissance Survey for Greenfield states: "In the Late Industrial period, Greenfield developed a prominence in the tap and die industry which would, by the early 20th century, give the town a worldwide fame." Continued losses of these sites deprive the town of major assets in its goal to maintain a desirable community possessing variety, depth and uniqueness. These resources cannot be simulated or replaced.

We also point out that expert opinion has cautioned against dam removals in this location citing possible further bank instability resulting from widening of the riverway.

Sincerely,

Marcia Starkey, chair

C/ Brona Simon, SHPO, Massachusetts Historical Commission
Joan Kimball, Director, Massachusetts Riverways Program
Mayor Christine Forgey

The COMMONWEALTH OF MASSACHUSETTS
BOARD OF UNDERWATER ARCHAEOLOGICAL RESOURCES
OFFICE OF COASTAL ZONE MANAGEMENT
251 Causeway Street, Suite 800, Boston, MA 02114-2136
Tel. (617) 626-1200 Fax (617) 626-1240 Web Site: www.mass.gov/czm/buar/index.htm

March 13, 2007

Mr. David Larsen, District Engineer
Engineer/Planning Division
US Army Corps of Engineers
696 Virginia Road
Concord, MA 01742-2751

RE: Deerfield River Watershed Study, Green River Fish Passage and Ecosystem Restoration Project, Greenfield, MA

Dear Mr. Larsen:

The staff of the Massachusetts Board of Underwater Archaeological Resources has completed its review of the above referenced project as detailed in the Corps's *Public Notice* of 15 February 2007 and offers the following comments.

The Board has conducted a preliminary review of its files and secondary literature sources to identify known and potential submerged cultural resources in the four (4) proposed project areas (Mill St. Dam, Wiley and Russell Dam, Swimming Pool Dam and Pumping Station Dam). No record of any underwater archaeological resources was found. Based on the results of this review and that the proposed underwater work is limited to areas of previous construction, the Board does not anticipate that this project will adversely impact potential submerged cultural resources. However, archaeological research indicates that certain types of environmental and topographical settings, particularly those that offered diverse resources on a consistent or seasonal basis, are strongly associated with the presence of prehistoric archaeological deposits. Such settings include the interface of land and water such as riparian systems consisting of rivers, creeks, and estuaries. Therefore, the Board expresses its concern that heretofore-unknown archaeological sites could be encountered during the proposed project activities.

Should heretofore-unknown submerged cultural resources be encountered, the Board expects that the project's sponsor will take steps to limit adverse affects and notify the Board, as well as other appropriate agencies immediately, in accordance with the Board's *Policy Guidance for the Discovery of Unanticipated Archaeological Resources* (updated 9/28/06).

The Board appreciates the opportunity to provide these comments. Should you have any questions regarding this letter, please do not hesitate to contact me at the address above, by telephone at (617) 626-1141, or by email at victor.mastone@state.ma.us.

Sincerely,

Victor T. Mastone
Director

Cc: Brona Simon, MHC
Kate Atwood, USACE

Commonwealth of Massachusetts
RIVERWAYS PROGRAM
Building Partnerships, Protecting Rivers

Joan C. Kimball, *Riverways Director*

March 15th, 2007

District Engineer
ATTN: Engineering/Planning Division (Mr. David Larson)
696 Virginia Road
Concord, MA 01742-2751

Re: Deerfield River Watershed Study, Green River Fish Passage and Ecosystem Restoration, Greenfield, MA

To whom it may concern:

The Green River represents one of the best opportunities for Atlantic Salmon restoration in Massachusetts. The Riverways Program fully supports efforts to restore and enhance fisheries habitat along this important river for Atlantic salmon, as well as other diadromous and resident fish species.

Over the past several years, the Riverways Program has worked actively with the Deerfield River Watershed Team – a group of agencies, non-profit conservation organizations, citizens and business working in the Deerfield River Watershed. For many years, stream ecosystem enhancement and fish passage on the Green River has been a priority project of the Deerfield River Team.

Riverways River Restore Program provided technical and staff assistance during the initial public outreach meetings and assisted in the drafting of renderings for the Wiley-Russell dam. In 2005, Riverways trained local citizens to conduct Shoreline Surveys – a visual survey – of stream corridor conditions and instream conditions along the main stem of the Green River. The Green River Stream Team, now known as the Friends of the Green River, serves as an active citizenry group along the Green River.

The Riverways program notes that the Corps mentions complete dam removal as the optimal method for fish passage. Complete dam removal not only restores fish passage and riparian functions, but it also eliminates long-term maintenance and liability to the Town of Greenfield, and makes possible additional opportunities for river-based recreation.

Riverways looks forward to working with project partners and providing further support to the Green River Fish Passage and Ecosystem Restoration project.

Sincerely,

Carrie Banks
Western MA Community Organizer

251 Causeway Street • Suite 400 • Boston, Massachusetts 02114 • www.massriverways.org • (617) 626-1540
Riverways Program, A Division of the Department of Fish and Game Dr. Thomas French, *Acting Commissioner*

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
NORTHEAST REGION
One Blackburn Drive
Gloucester, MA 01930-2298

MAR 2 0 2007

Mr. David Larson
District Engineer
Engineering/Planning Division
U.S. Army Corps of Engineers
696 Virginia Road
Concord, ME 01742-2751

Re: Green River Fish Passage and Ecosystem Restoration

Dear Mr. Larson:

The National Marine Fisheries Service (NMFS) has reviewed the Public Notice and the Somerset & Searsburg Dams (Deerfield River Watershed Study) Draft General Investigation Feasibility Report and Environmental Assessment (Draft EA) which describes the U.S. Army Corps of Engineers, New England District's proposed environmental restoration project on the Green River in Greenfield, MA. The proposed project includes the following activities: removal of the Wiley & Russell and Mills Street dams, and installation of fish passage at the Swimming Pool and Pumping Station dams. Contaminated sediments will be removed from the impoundments associated with the dam removals. The timing of in-water activities will be coordinated to avoid impacts on upstream and downstream migrating anadromous species. Implementation of this project is authorized under Section 206 of the Water Resources Development Act of 1996.

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) and the Fish and Wildlife Coordination Act require federal agencies to consult with one another on projects such as this. Insofar as a project involves essential fish habitat (EFH), as this project does, this process is guided by the requirements of our EFH regulation at 50 CFR 600.905, which mandates the preparation of EFH assessments, and generally outlines each agency's obligations in this consultation procedure. We offer the following comments and recommendations on this project pursuant to the above referenced regulatory process.

General Comments

The Green River is a tributary to the Deerfield River within the Connecticut River watershed. According to the findings of the Draft EA, the Green River historically provided migratory, spawning, and nursery habitat for Atlantic salmon, American shad, blueback herring and alewife, sea lamprey, and American eel. The construction of dams has limited access to upstream habitat and reduced or eliminated presence of these migratory species in the Deerfield and Green River watersheds.

Downstream of the Green River, fish passage has been implemented on the Connecticut River. To date, anadromous species have volitional access up the Connecticut and Deerfield Rivers to the first dam on the Green River. The goal of the proposed project is to restore access for these migratory species into the Green River watershed. Removal of the first two dams on this system and construction and operation of fish passage facilities on the third and fourth dams will provide the necessary access to upstream habitat – including 8.7 miles of mainstem habitat and a total of 21 miles of potential spawning and nursery habitat - resulting in long-term ecological benefits for each of these species. As such, NMFS supports this restoration project. In the short-term, however, construction activities related to the proposed project would adversely affect the habitat value and potentially have direct impacts on migrating juvenile and adult diadromous finfish.

Essential Fish Habitat Conservation Recommendations

As noted in the EFH assessment included in the Public Notice and the Draft EA, the Green River has been designated as EFH under the MSA for Atlantic salmon (juveniles and adults). Only stocked juveniles are currently present above the Wiley & Russell dam, the first dam on the Green River. However, seven adult salmon were noted in 2005 at the base of the Wiley & Russell dam. The proposed project would adversely affect EFH by increasing turbidity and noise during the migration period. Also, while the project plan includes removal of contaminated sediments, there remains the potential for the incidental release of contaminants. NMFS recommends pursuant to Section 305(b)(4)(A) of the MSA that the Army Corps of Engineers (ACOE) adopt the following EFH conservation recommendations:

1. In-water activity should not occur between April 1 and June 15 of any year to protect out migrating juvenile salmon. Because juvenile salmon are limited in their mobility, this recommendation is necessary to avoid mortality or migration delay that may be associated with construction activities.
2. Prior to removal of the dams, efforts should be taken, to the greatest extent practicable, for the removal of contaminated sediments. An evaluation of the remedial site(s) should be completed to ensure targeted materials were removed.
3. Erosion control methods such as coffer dams, as identified in the Draft EA, should be implemented to avoid impacts on juvenile salmon that may be within the project area prior to the identified migration window. During their growth and development, juvenile salmon do move within a river system. This recommendation is needed to protect those juveniles that may drop down prior to the migration season or migrate outside this identified window. In addition, adult salmon may be in this area between May and October and this recommendation will help protect those adults.

Please note that Section 305(b)(4)(B) of the MSA requires the ACOE to provide NMFS with a detailed written response to these EFH conservation recommendations, including a description of measures adopted by the ACOE for avoiding, mitigating, or offsetting the impact of the project on EFH. In the case of a response that is inconsistent with NMFS' recommendations, Section 305(b)(4)(B) of the MSA also indicates that the ACOE must explain its reasons for not following the recommendations. Included in such reasoning would be the scientific justification for any disagreements with NMFS over the anticipated effects of the proposed action, and the measures needed to avoid, minimize, mitigate, or offset such effects pursuant to 50 CFR 600.920(k).

Please also note that a distinct and further EFH consultation must be reinitiated pursuant to 50 CFR 600.920(l) if new information becomes available or the project is revised in such a manner that affects the basis for the above EFH conservation recommendations.

Fish and Wildlife Coordination Act Recommendations

Anadromous species such as alewife, blueback herring, and American shad have been observed in the lower Green River. Sea lamprey and American eel are thought to historically inhabit the Green River. The Draft EA does not include data to determine the current presence or absence of lamprey or eels in the river. These fish are unable to migrate to upstream habitat due to the lack of proper fish passage at the Wiley & Russell dam. American eels may be able to pass the existing structures, however, once eels reach a certain size, they are unable to pass vertical structures. The proposed dam removals and fishway construction will greatly benefit these species by opening the river or improving potential access. The conservation recommendations for the protection of EFH will serve to protect diadromous species under the Fish and Wildlife Coordination Act. Therefore, no additional recommendations are necessary.

Conclusions

In summary, NMFS supports restoration projects of this type. Complete dam removal is the best means for restoring fish passage and the natural riverine condition. NMFS recognizes that removal of dams providing a public service may not be practicable. In these circumstances, volitional passage, such as vertical slot or denil fishways, can provide effective fish passage and reconnect segments of a riverine system. The short-term effects of implementing restoration projects cannot be overlooked. Therefore, NMFS recommends the in-water work not be conducted between April 1 and June 15 of any year; that all contaminants be removed prior to beginning construction activities; and erosion control measures such as sheet pile coffer dams be utilized to avoid impacts on the resources. We look forward to your response to our EFH conservation recommendations for this project. Should you have any questions about this matter, please contact Sean McDermott at 978-281-9113.

Sincerely,

Peter Colosi

Peter D. Colosi
Assistant Regional Administrator
for Habitat Conservation

cc: M. Bartlett – FWS
M. Colligan – PRD
J. Catena - RC